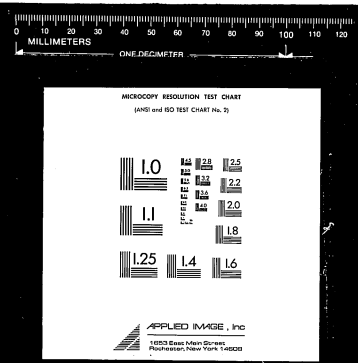

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Thomas A Edison Papers

A SELECTIVE MICROFILM EDITION

PART III
(1887–1898)

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A Note on the Sources

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Notebook, N-94-10-08

This notebook covers the periods October 1894-August 1895 and February 1897-September 1898. It was used by Joseph W. Harris and Jonas W. Aylsworth, probably at New Jersey and Pennsylvania Concentrating Works in Ogden, N.J. The book contains notes regarding various ore milling operations, including the electrolytic separation of iron ore, the bricking of ore concentrate, oil and lubrication experiments, and the roller feed at the plant. There are also routine ore assays and notes relating to sand volume experiments. The front cover is labeled "Record of work done in Assay Room" and "General Work." The pages are unnumbered. Approximately 160 pages have been used.

The material relating to sand volume experiments and ore assays has not been filmed.

Nov 8th 1894

Chemical Experiment, dissolving metallic iron of electrolyzer.

Saturated solution of Na Cl for electrolyte.

Piece of wrought iron, polished weighing 17.7 grams, immersed so that an area of 2.11 square inches was acted upon, connected to + pole of dynamo, (oxygen pole) treated with a current of 5 amperes for 2 minutes, lost 180 milli grams. This equals 18 mg. per amp. per minutes, or in this expt, 8.533 mg per amp. per minute, per sq. in.

(see next Page –

Electrolyte exptl. with sol. Na Cl,
[illegible] 17.650 grams,
[illegible] at 9.00 P.M., Nov. 9th –
current [illegible]

Expt. aborted

Piece cast iron weighing
179.540 grams placed in
[illegible] solution of Na Cl
current 0.8 amps. passed
for 11 hours –
started at 9.30 P.M., Nov. 9th
stopped at 8.30 A.M. Nov 10th.

~~Loss of weight~~
Plate weight 172.130 grams
= a loss of 7.410 grams,
11 X 60 = 660 minutes
660
0.6
396 ampere minutes, 396)7.410 18.71 milli-grams.

The cast iron lost 18.71 milli-grams per ampere minute, in Na Cl, against 18 milli-grams per ampere minute with wrought iron. This may be due to local action, or to a more reliable test, owing to a longer time being allowed.

Nov. 10th

Cast iron electrode weighing 172.130 grams immersed in a saturated solution of ferrous sulphate, ($FeSO_4$) at 11.25 A.M., current 0.4 amps. for about 30 minutes then 0.2 amp. for balance of time – stopped at 3.25 P.M. Nov. 10th
= 15.4 mg. per ampere minute

Nov. 12 - 1898

Experiment with piece of cast iron
having an immersed surface of
1/4" square = 1/16 of a square inch
current density 25 amp. per sq.
inch. current 0.5 amp. 2 minutes.

Weight before	4.070 grams
Weight after	4.040 "
loss	0.030 "

= 6.55 mg. per amp. per minute,
nearly the reciprocal of capillarity.

The figures given for which capillarity was partly avoided by covering iron electrode with gravy leaving only 1/4 square exposed =

4.030
4.010
0.020 grams loss

Current 0.5 amp. =
4.44 mg. per ampere minute.
This result is probably most accurate.

of any yet obtained.

Nov. 12th –

Experiment on working of old grease

Some grease boiled with HCl separated oil collected & weighed.

10 grams burnt lime slaked in about 20 grams hot water, water was barely enough to combine with lime,

19½ grams unwashed oil were added, stirred with bamboo & heated on steam mixture was then transferred to water & united some time with pestle. It was quite slippery, but did not seem to have any body, owing to the presence of mechanically mixed water, after heating over burner for some time, to expel water, it was considerably improved.

In making the grease, the water must be expelled, & the mixture must be worked on ground, or it will not always be satisfactory.

Mr. 22nd 1894

Experiment with distilled mug from mould which of brass, to determine the amount of iron salts electrolyzed in a solution of Fe SO4

Current used 8.55 d. m

2 amps, [illegible] – 1/2 [illegible]

surface = 100 ⁿ

current soon fell to below 1/2 15 amps + it did not raise — note 130 at terminals of bath –

liquid soon [illegible] [illegible] very hot, mug became covered with a coating of anhydrous ferrous sulphate which was cut off by a knife with different current stopped after 1 hour & 10 m before the end of the mug was [illegible]

652.2 grams, after the expt, weighed 648.4 grams, that shows a loss of 3.8 grams.

The current probably averaged 15 amps, the average measured was not accurate, on account of the fluctuating of the alternating current.

Before passing current, the ring calipered 3 1/8" full, after the operation stopped, it calipered 3 1/8" scant, the diff being about 1/64".

At the rate of 4.4.4 mg. of iron being dissolved per ampere minute and assuming the average current to have been 14.5 amps, and the time of action to be 1 hour (the action was irregular, owing to failing to) the results obtained correlate the theoretical results,

actual loss, 3.8 grams

loss per ampere-minute 0.00444

60

.26640

average current, amps 14.5

theoretical results, grams 3.86 28 0.0

actual loss grams 3.8

Nov. 23 - 1894

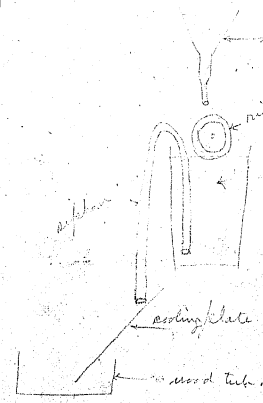
Experimental distillation in Fe Sol.

Our apparatus at 25 cents, has
a capacity of 20 cu. in. surface
[illegible] 14 x 2 sq

It was so arranged that a [illegible]
[illegible] was kept running into
[illegible]

[illegible] and the [illegible] of the
[illegible] [illegible] was
[illegible] running over the [illegible]
so as to keep the ring over
the circulating liquid at [illegible]
the temperature [illegible] so that
one could place the hand on it.
The liquid was removed from jar
by means of a siphon, that fell
[illegible], on account of the liquid

Seing full & hydrogen bubbles.



A number of experiments were made with different current densities to determine the most economical current density.

Electrodes about 1½" apart.

4 cgs. in surface

[illegible] immersed.

Amps	Volts
3.3	5
5	9
10	10
11.5	16
12.0	16

Electrodes ½" apart

4 cgs. in surface immersed

Amps	Volts	Watts consumption per sq. cm. of surface
3.2	3.5	
5.5	6.5	1.46 watts
10	10.5	2.36
13.0	12.0	2.70

Experiments with Nitrate & chloride of iron.

1 cg. in of surface, immersed in experiments.

Nitrate of iron

Amps	Volts
3	6
6	14½
12	20
21½	32

Chloride of iron

Amps	Volts
3	10
6	18
11	27
19	36

(over)

To a [illegible] solution of [illegible] [illegible] 125 c.c. of water of [illegible] 11.564 [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

Amps	Volts	Volts expressed per unit of area, each volt = 0.45 watt
2	2	
6½	6	1.35 watts
12	9.5	2.13 "
26	15	3.37
38	20	4.5

In the above experiment the iron block weighing grams iron, its weight in the [illegible] being 633.5 grams.

Expt. on filling brake tube with sand.

tube holds 27.6 grams 14-20 mesh sand.

tube allowed to fall through 2.5 inches on an iron block to settle the sand, allowed to fall 50 times, then refilled, dropped 50 times more, tied, and [illegible] a total number of 200 drops had been given to it.

Filling different mesh sand, more stuff was put in than with all 14 mesh.

200 mesh stuff, with impalpable dust removed was used along with 110-130 mesh + 14-20 mesh

24 grams 14 mesh
6 " 110-130 "
6 3/4 " 250 mesh

36.75 grams
27.6 "
9.15 " increase

27.6 / 9.15 c.c.
33.1 % increase

Expt with sand –

C.C. measure filled to 10 c.c. mark with 14 mesh sand, & shaken down, water was then added from a measure to fill up the spaces, it required 4 1/2 cc H_2O = 45 % of volume of sand.

C.C. measure filled to 10 c.c. mark with the 24 grams of 16 mesh, 6 grams 110-130 – 6.75 grams 250 mesh, added space filled with H_2O, it required 3 cc H_2O to fill it, = .30 % of volume of sand –
Duplicate expt made with nearly same results.

Experiment with iron ring,

immersed to a depth of about 4 ozf in, in sulphate of copper, having a felt used rubbing against the ring, as ring rotates; so that any ppt. cu. would be rubbed off.

Kept rotating for 1 hour,

before expt, 633·5 grams
after expt, 633·75 "

0,25 " lost.

The solution consisted of 1 lb copper sulphate to 1 gallon water,

Copper did not deposit very well, probably owing to the chemical combination of iron with carbon in the ring

Expt with iron

Weight 632.7 grams

Immersed in solution of ferrous sulphate containing free H_2SO_4 & about 5-10% sulphate of ammonia

Current used 4.25, started stopped at 5.25

Weight before expt, 623.2 grams

= 9.5 grams loss

A surface of 4 sq. in was acted on.

Amps.	Volts
18	11.5
19	14 1/4

The iron results is not liquid but when cold it was 23.5 — 20.5

a little NH_4Cl added at start of expt. gave much better results

17 amps. 8.5 volts.

4 sq. in surface immersed

Shepheards expt with $FeSO_4$ containing NH_4Cl.

Started at 8.50 P.M.

Stopped at 9.50 P.M.

Average Current about 7.5 amps.

Weight after expt, 614.7 grams

8.5 = weight lost

Amps	Volts
13	10
9	6.5
5.5	5
4.5	4

Feb 11th 1895

Assay of old Grease for Calcium

5 grams used.

Contains 1.2 % Ca.

400 lbs grease contains 4.8 lbs Ca

Hcl of 1.123 Sp.G. contains 24.85 %
Hcl gas = 24 %, Cl gas

4.8 lbs Ca requires 8.52 lbs Cl gas
to make 13.32 lbs $CaCl_2$

400 lbs grease requires 36.18 lbs
Hcl of 1.123 sp.g.

400 lbs old grease will require 6.72 lbs
anhydrous Ca O = 1.68 %

Experiment with old grease

20 grams heated + treated with 2 grams
Hcl of 1.123 sp.g, boiled, water filled
filtered reaction neutral.
= equiv of 1.0 % Hcl

20 grams old grease heated + treated with 2.25 grams HCl of 1.123 sp.g. reaction of watery fluid, acid.
Oil was dirty, but dirt seemed to separate on boiling the oil, excess of 25% HCl

20 grams old grease heated + treated with 2.5 grams HCl of 1.123 sp.g. reaction of watery fluid acid. Oil still dirty, but cleared up on boiling excess of 39% HCl

Expt on recovery of old grease.

2 lbs old grease taken off bearings in French engine room and digested with 3.6 ozs HCl of 1.123 sp.g. until lime had been dissolved + a perfectly fluid oil obtained. Oil was very dirty, the watery solution was acid. Oil was separated, filtered through muslin, again heated with same acid solution, separated, filtered through paper filter + used as stock for subsequent experiments. Oil had a brownish cherry red color by transmitted light + slight fluorescence.

1.9 grams anhydrous lime were

slaked in hot water and floated over, as it contained some sand, 100 milligrams more CaO were added (5%)

4 ozs separated oil were combined with the lime mixed well in a mortar, heated to drive off surplus water which was combined with the lime. It was a little darker in color than new grease, but in all other respects seemed to resemble it,

a sample was digested with water & tested with phenolphthalein for acid, but it was found to be neutral.

The % of anhydrous lime mixed with the oil is 1.68, + 5% for sand, makes it 1.75% by weight

In separating the sand in the lime a large excess of water must be used which can then be filtered off.

Experiments on the recovery of
55 grease, furnished by the
Krupp. Mfg. Co, New York.
Grease is a pure Hydrocarbon,
Old grease taken from journal of
Intermediate Roller.

#1

Dissolve in about 6 thousandth weight
of gasoline, filter, distill, grease
is left in retort in a pure
state.

2

Boil with an equal weight of
1.1154 sp g H_2SO_4, until a consider-
able quantity of yellow greasy
foam accumulates on surface,
separate from H_2SO_4. grease
still contains the dirt, but it is no

in the same state it was in before.

Grease is then boiled with a 1.04 Sp.G. solution of Na_2CO_3 (Soda) to neutralize any acid remaining in the grease.

Grease still contains the dirt, lime, separated from the Na_2CO_3 solution, washed with water, separated, boiled to remove water. During this boiling, all the dirt settles to the bottom of the dish and will not recombine with the grease even with violent stirrings. Can be filtered off perfectly clean, or can be decanted after settling.

Grease recovered with H_2SO_4 easily

flackens on heating.

#3

Boil with an equal weight of HCl of sp.g. 1.02 being a 15% sol. by volume, until a yellow foam accumulates on the surface in considerable quantities, separate from acid solution, boil with 1/2 its weight of Na_2CO_3 sol of sp.g. 1.04, to neutralize any free acid separate, wash, separate, boil to remove mechanically enclosed water, when all dirt will separate can then be filtered, has a pure color does not char on heating, except like fresh grease.

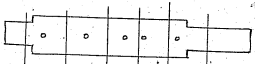
Experiment with oils, determining quantity that flows through a small hole.

A mixture of 1 part crucher Oil 2 parts Fuel oil (from Bayone Oil works) has a Sp.g. of 0.88.

It is necessary to mix about 1½ times its weight (weight of mixed oils) of 200 mesh so 90 oz, with it, in order to give it the same consistancy as crucher oil.

5/32"		3/16"		5/32				
1 hour	403 grams	1 hour	546 grams					Crucher Oil
20 sec.	28 c.c	20 sec	41 c.c.					Machinery Oil
30 sec	128 c.c.	20 sec	220 c.c.	20 sec	272 c.c.			Fuel Oil
20 sec.	115 c.c.	20 sec.	144 c.c.					Lima Oil

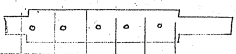
Tests of flow of Grease through holes in #2 Cleveland pin, forced by a grease cup.



	Temp	Length in inches					
#1 Grease	60°	4"	1/4"	0	0	0	Is a lime soap.
Old Std. Oil	110°	3"	1/2"	1/16	1/16	1/32	Will not hold
Gr. Grease	125°	2"	1/2"	1/16	1/16	1/32	its shape above
Melts at 180°	140°	4"	3/8"	3/8"	1/16	1/32	140° F.
		Kruppe Mfg. Co. Grease					
Grease #26	60°	3/8"	11/8"	1/8"	1/8"	1/8	Is a fine lye
Kruppe Mfg. Co.	60°	2"	5/8"	1/8"	1/4"	1/8	ancorium
Melts at 95°	80°	1"	7/8"	3/4"	5/8"	1/2	Will not hold its
							shape at 80°.
Grease #40	75°	Is very hard to turn					Is a soap.
Melts at	80°	4"	1/8	1/8	1/16	1/16	Will not hold
176°	92°	3"	1/4	1/4	1/4	1/8	its shape
	140	1"	1"	1	1	3/4	above 140°
Grease #45	45°	4"	7/8	3/8	1/16	0	Is a mixture
Melts at	65°	2 1/4"	5/8	3/16	1/16	0	of 55 grease &
130°	72	1 1/2"	3/8	1/4	1/16	0	a soap.
	80	1 1/4"	1	3/8	3/8	1/16	Will not hold its
	90	1 1/2	3/4	3/8	1/4	1/16	shape above 90°.
							Turns stiff
							at 45°.

	Temp	Length in inches					
Grease #46	58	1/2	3/8	1/4	3/32	1/16	Appears to be all
Melts at 110°	70	3/4	1/2	3/8	1/4	1/8	hydrocarbons
	78	1	7/8	1/2	3/8	1/4	Will not hold its
							shape at 78°
Grease #55	57	1 1/2	1/2	3/8	3/8	1/8	Is a pure Hydro-
Melts at	70	5/8	3/8	1/4	1/4	1/8	carbon.
96° F	76	3/8	1/4	3/32	3/32	1/16	Will just hold its
	84	1/2	3/8	1/4	1/4	1/8	shape at 84°
Grease #58	65	1"	1"	1"	3/4	5/8	Will not hold its
Melts at 90°	72	1"	1"	1"	1"	1"	shape at 72°
							Appears to be a
							pure Hydrocarbon
							easily blackened
							by heat.
Grease #59	65	1	7/8	3/4	5/8	1/2	Is a pure Hydrocar-
Melts at 85°	76	1/2	3/8	3/8	1/4	1/4	Will just hold its
							shape at 76°
Grease #60	60°	2"	1/8"	0	0	0	Is a hydro-
Melts at 80°	66°	1"	3/4"	1/2	1/4	1/8	carbon mixture
	70°	1"	1"	1"	1"	3/4	Will not hold
							its shape above
							66°

	Temp	Length	Inches in inches				
Grease #61	48	1 1/2	1/2	1 1/4	1/4	1/32	appears to be
Melts at 110°	65	3	1"	1/4	1/4	1/8	pure Hydrocar-
	70	1/2	1/2"	3/8	3/8	1/8	Will not hold
	80	1/2	1/2	1/2	1/2	1/2	its shape at 80°
Grease #63	65°	1"	1/2"	1/4	1/4	1/8	looks like a mixture
Melts at 115°	75°	1/2	3/8	1/4	1/4	1/4	of soap & a soap
							Will not hold its
							shape at 75°
Grease #64	60°	1 1/2	3/16	0	0	0	Resembles #55+
Melts at 102°	70°	2	3/4	1/8	1/16	0	a soap.
	82	1	3/4	1/8	1/8	1/16	Will not hold its
	88	1 1/4	1	1/4	1/8	1/16	shape at 88°
Grease #66	75°	Difficult to turn					
Melts at 105°	90	2 1/4	3/4	3/16	1/16	1/32	Is a soap
	105	1 1/4	3/4	3/8	1/4	1/8	
	116	1 1/2	3/4	3/8	1/4		Will just hold its
	120	3	2	3/4	3/4	5/8	shape at 120°
Grease #70	45	3"	0	0	0	0	Contains a substance
Melts at 126°	55	2"	0	0	0	0	resembling a soap
	76	1 1/2	1/8	0	0	0	Will not hold
	85	1 1/2	5/8	1/4	1/8	0	its shape at 95°
	95	1	1/2	1/4	1/8	1/16	



	Temp.	Length of grease in inches.					
Brass + 75							
Melts at 115°	65	1 1/4	3/16	1/32	0	0	In a stiff +
	70	1 1/4	3/8	1/16	1/32	0	grease compound.
	80	3/4	3/8	1/8	1/16	1/32	Will not hold
	90	3/4	3/8	3/16	1/8	1/16	its shape above 90°

June 7th

Experiments made to determine the volume of "pores" in a baked brick.

Brick contained about 40% larger than standard 50 mesh ore, had 20 cts. much mixed with it was very hard + fairly satisfactory.

	grams
Weight of brick before immersion	298.5
" " " after "	313.2
Weight of gasoline absorbed	14.7
	cc
Vol. of gasoline before immersing brick	125
Vol. of gasoline after immersing brick, and brick had absorbed all it would,	220.5
Vol. of gasoline after removal of soaked brick	98 cc
Vol of gasoline absorbed by brick, by diff	27 cc
Total cubic vol. of brick including pores,	122.5 cc
volume of pores in brick,	27 cc
volume of solid matter,	95 cc

(over)

Volume of piers in brick 22 2 0

Volume [illegible] walls in brick 78 2 0

June 19th 1895

Experiments with iron soaps, &c.

Iron soap lubricants

Iron soap formed of 5 cts per lb.

1 lb. soap	100 lbs water,	cut	5 cts	per 100 lbs	
2 " "	100 "	"	"	10 "	" " "
3 " "	100 "	"	"	15 "	" " "
4 " "	100 "	"	"	20 "	" " "
5 " "	100 "	"	"	25 "	" " "
6 " "	100 "	"	"	30 "	" " "
7 " "	100 "	"	"	35 "	" " "
8 " "	100 "	"	"	40 "	" " "

After standing one hour, in room at a temp. of 85°F, # 1-2-3 are still fluid, the remainder are stiff.

These mixtures are to be used as lubricants for the elevators.

(are not satisfactory)

July 8th 1895

Experiments with dirty grease.

Tried dissolving 25 parts of dirty grease in 75 parts of fuel oil, heating, filtering through muslin and evaporating the filtrate to distil off the oil & thus recover the grease. It is necessary to refilter the oil as many as five (5) times before a sufficient sediment has collected to clean the oil and grease from the dirt. On heating the oil & grease mixture to drive off the oil, the grease decomposes & carbonizes and after nearly all the oil has been driven off it becomes sticky on cooling.

The same results were had with crude lime oil and oil from oil tank.

On treatment with gasoline and filtering through paper, and evaporating the grease can be recovered, but the gasoline is difficult to remove entirely, and towards the last, the grease decomposes.

A mixture of 25 parts grease and 75 parts of oil (fuel, lime, or tank oil) can be used in elevators in place of mixture of 1 part crude oil and two parts fuel oil used at present.

July 23 - 1895

Tested with current on magnet 12 amp.
Test of Roller feed on 8" magnet -
Iron roller, 1" diameter.

The consisted of about 97 % rag ore, (through coarse 50-mesh screen) & 3 % of 14-mesh ore. There was a number of large pieces among the coarse ore.

Slot above roller feed was ½" wide
Roller feed turned by hand, turns counted & timed.
at the rate of

24 revs.	per minute,	gives 1125	lbs per foot per hour
30 "	"	" 1305	" " "
36 "	"	" 1485	" " "
42 "	"	" 1665	" " "
60 "	"	" 2115	" " "
90 "	"	" 2925	" " "

The 3/8" holes 1 3/16" between centers, used at present give 1413 lbs per foot per hour.
The roller feed should make 33 2/3 revs. per minute to give the same amount (by calculation)

Muck in Muck house

Aug 9th 1895

Rosin 100

Lima Petroleum 45

Rosin 700 lbs -

Oil 320 lbs -

Rosin melted first, then Oil run in.

This proportion was used on account of hot weather

In winter it will be necessary to use more oil (See Water in Bucking Concentrates, special note book)

Aug 10th 1895

Standard mush consists of Rosin 100
Petroleum 50

It may be necessary in very cold weather to raise it to
Rosin 100
Petroleum 57½
because in cold weather Standard mush gives too many "balls".

The following is a scale of lbs of standard mush at different prices.

10 cts worth	=	22.5	lbs	per ton
11 " "	=	24.75	"	" "
12 " "	=	27.00	"	" "
13 " "	=	29.25	"	" "
14 " "	=	31.50	"	" "
15 " "	=	33.75	"	" "
16 " "	=	36.00	"	" "
17 " "	=	38.25	"	" "
18 " "	=	40.50	"	" "
19 " "	=	42.75	"	" "
20 " "	=	45.00	"	" "

The mixers are to receive 400 lbs concentrates per minute and mush lift sprocket to run at 1⅔ revs. per minute to give 45 lbs shot mush per ton, = 20 cts. = 8 lbs mush per 400 lbs ore

Bricks are to be baked at a temperature between 475°F to 500°F, for one hour, if baked at a lower temperature, they may soften again on heating, if baked at a higher temperature, they may oxidize, + become brittle after cooling.

Bricks should not absorb more than 1.5% water in 24 hours, if standard mark is used.

assay of 50 meals sent for
[illegible]
Alumina ✓ little.
Potash ✓
Soda -

fuel oil cake all right, if it is a little warm.

This mixture was tested in bearings, but was found to be too thin. It should be say twice as thick.

Eureka made with 10 parts soap to 180 parts water, is thick on cooling, is satisfactory

Made bucket full of alum, 1-18, using 1 lb soap : 18 lbs water

October 8th 1894

Experiments made with a solution of drying soap in water, to be used as a lubricator

Several solutions made, and one consisting of 10 parts soap, 350 parts water, gives good results.

The soap costs 7 cts per 8 oz. cake.

It has no effect on rusty iron, expt. tried by boiling the soap water containing rusty iron, for 3 days, the water was then oxidized with nitric acid, filtered, & ammonia added, no iron ppt. came down, nor did the solution become tinted due to traces of iron.

In making, do not boil solution longer than necessary, or the soap appears to separate in finely divided particles, which do not seem to be slippery.

This solution passes through a sight-110 mesh stuff to settle to the depth of 1 inch, through 8" of solution, some 40 mesh stuff settled in 1/2 minute.

Experiment made with

18 1/2 grams Rosin

25 cc sld sol. Na_2O = 2 1/2 grams Na_2O

and 95 cc H_2O.

The 25 cc Na_2O was diluted to 100 cc first, rosin added, then water, then more rosin.

Experiment was made on steam bath.

There was a residue of 0.9 grams of rosin which did not combine.

The solution measured 90 cc, 30 cc of water was unused, a few drops of resinate added, then mixed with the 90 cc + warmed together, + poured in beaker to cool slowly.

After cooling, a pt. of Rosin came down

Solution was placed in a tall graduate, it took 6 minutes for some thorough shaking, descended fairly slow.

A very finely divided pt of Rosin came down, which partly helped to assimilate the rest.

Expt with Resinate of Soda —

Na_2O	2.5 grams
Rosin	22.0
H_2O	80

Cost 15 cts —

There was a residue of 3 grams of rosin which did not seem to combine with the soda —

This was then diluted with 1/2 its volume of water, making it cost 10 cts per 100 lbs —

The addition of cold water ppts. Rosin which is partly dissolved on warming.

The 15% of Rosin which separated should be left out in the first place, + the additional water added which weighing the stuff.

On mixing with ore in a tall glass the particles of ore agglomerated + on

Expt with Resinate of soda as follows

Na_2O	2.5 grams
Rosin	22½ "
H_2O	80

The Rosin did not all combine, about 10% remained in dish, when fluid was poured off, + ore added & shaken up, the ore seemed to "ball" up + deposit in lumps. It deposited very slow, owing to the viscosity of the solution. On diluting with water, the Rosin separated.

Cost 15 cts per 100 lbs —

The agglomerating of the particles of iron may have been due to particles of free rosin cementing them together

Experiment made with a solution of Resinate of soda, made as follows,

2.5 grams Na_2O (Roland Soda) dissolved in 25 cc H_2O
75 cc H_2O added.

22.5 grams powdered Rosin added.
a small quantity did not combine with the soda solution.

This mixture was put in a tall glass cylinder, & mixed with ore, to see how rapidly the ore settled.
The solution was not viscous enough.
Cost 12.6 cts. per 100 lbs.

Notebook, N-95-09-11

This notebook covers the periods September-October 1895 and December 1897. It was used primarily by Jonas W. Aylsworth, probably at New Jersey and Pennsylvania Concentrating Works in Ogden, N.J. Most of the book contains notes regarding the bricking of iron ore concentrate. Included is a 10-page entry by Edison relating to the bricking process. At the end of the book there are logs of additional bricking tests and rough records regarding running and stoppage times at the Ogden works. The front cover is labeled "Bricker Experiments." The inside front cover is inscribed "J W Aylsworth." The pages are unnumbered, and the book has been used in both directions. Approximately 90 pages have been used.

About 40 pages of rough records regarding running and stoppage times have not been filmed.

The Briquette plant was started with mix consisting of Rosin 2 parts Lima Oil 1 pt. 3.3 lbs to the ton of ore was used.

Very few whole briquettes come through breakage = about 90%.

Apparatus was put in to handle the briquette more gently soon then the breakage was not materially decreased.

Experiments were tried to see if much was OK. Lime much made up with some proportion appeared to be identical with much from the bottles. Then some was mixed with the ore 33 lbs. to ~~ton~~ this appeared some or that mixed in briquette mixers –

Sept 11 / 95

Experiments were made with a stretcher mach.

#1

Rosin 100
Oil 35

Mixed with ore in proportions of Ore 2240 Mach. 33
Made a much stronger + better briquett.

#2

Rosin 100
Oil. 25
Mixed in proportions of ore 2240 Mach 33
Was difficult to mix but when the ore was warmed to about 100°F. it mixed all right.
The briquetts were very strong could be handled & lift without breaking

Loaves of #1 2
were baked & came out
very hard though while
hot & before the baking has
been completed they could
not be picked up.
It was concluded that
the pressure in bricken machine
would improve them in this
respect.

3

#2 much mixed in proportion
of 2240 ou to 25 much.
Quite as hard as #2

4

#2 much mixed in proportion
of 2240 ou to 20 much.
very hard much dagger &
better stuff to feed down shutes.

The briches were started with # 2 mesh 33 lb to ton,

mixed all right but were to sticky & did not feed to the briches all right.

Then some # 4 was tried this ones did not feed well & appeared to be too dry but the percent of good briquette were better than previous trials.

A average test of mixed ore taken at 8 different intervals of time was 14 lbs to ton.

This was tested by dissolving coal tar mixed with benzene & then alcohol & weighing the ore when dry & allowing for the moisture in ore previously determined.

Experiments on a quick way of testing the oil to see that much is O.K.

A weak solution of NaHO is made up of such strength that 1 cc neutralizes (i.e. 17 grammes of 2 cc to 100 mmch. (or the reverse in litters.) The mmch is dissolved in 50 cc. of wood alcohol, of which the solution has been affected 10 drops of moderately strong solution of phenolphthalein in alcohol, are added.

100 grammes of oil are taken & mixed with 50 cc of alcohol & heated, can bring latter to shake well frequently.

The wood alcohol was tested & 50 cc were found to take $\frac{1}{10}$ cc of N/10 sol before it became neutral. Hence $\frac{1}{10}$ cc must be deducted from the results in practice.

The std soda solution is added from a burette until a red color appears & remains after well shaking.
The mixture must be stirred while the std sol is being added.

The crude oil contains a little acid that will not much and it will make no difference in results as the solution is always discharged with mucks of not with rosin.
10 cc std sol = acid in the Oil.

1 cc of the std sol = .158 gm rosin.

Some fresh muck was made up of exact proportions 100 rosin to 25 Oil. This muck when tested gave —

1 cc std sol = .1923 of 100 to 25 Muck
This is correct the muck in bottles contains less oil than 25 to the 100
The amount of rosin in the std sample of muck was determined exactly by the std sol of Soda.

A test of old mesh tinnf
was in bottle when briket plant
first started up gave Resin 100 to Oil 43.8

Heating briquette in iron
tube mesh mesh is seen off

Wt of ½ brick. 148.75 (before heating)

" " ½ " 146.6 (after ")

mesh in brick, = 55 lb. to ton.

The briquette after heating to
500° for about 1 hr. was [illegible]
hard.

Wt of mesh in brick = 2.47

Loss of weight in heating = 2.15

Of this loss, .44 can be considered as
moisture contained in the ore

This leaves a loss of 1.71 mesh
or .76 gm of mesh remained
in 148 gm ore.

94.85 : 2 = 2265 : 25
25
47425
18970
2371.25 : 2265
2265 1.04
106.25

Determination of Residue left in briquette after baking.

The briquette was a perfect mixture of 25 lb smack to tone on.

It was baked 40 minutes between 450°F & 470°F.

Wt of briquette. = 94.85 gm.
" " smack taken = 1.04 "
Loss of smack in baking = .55
Residue remaining = .49

A briquette was quite strong notwithstand the alcohol test from some time but ultimately softened somewhat, but did not entirely collapse.

#9. 10/3/91

[illegible]

[illegible] much [illegible] [illegible]

[illegible]

From [illegible] cotton cold at [illegible]

[illegible] 40 [illegible]

[illegible]

The moisture much 2.7 = 20 lbs per ton.

B briquette pressed in wire

[illegible] before baking 15.3

Baked in 35 minutes at 480°-660°F.

Wt of briquette after baking. 15.2.15

" " much in briquette = 1.37

Loss in wt = .85

Material remaining = 1.52

#10

Resin 100

Resinoid 50

Na_2O 2 (found)

Ferrous Sulphate 8.8 to be added after the soda has gone in.

no good.

#11

Precipitated nitrate of iron is mixed with (100 : 50) mark it dissolve.

12 10/8/95

Baking Experiment

Bar with 4x 4 to stone

#1 Baked in ▭ from Tem 510° 1½ hr.
No apparent oxidation
Brittle granules with cold water
while hot
Broke in two when tossed up 10 ft.

#2 Baked on list ▭ ~~same as~~ #1
Cardboard on top corners so that
it was crumbly
broken without nothing.
Tossed up ten ft did not break
but corner broke off when it struck.

#13

Briquette with up to tons.
Baked in circle 430 - 520° 1½ hrs.

#14

Same kinds of briquettes as #13
Baked with five acres grain all around.
Baked at 430 - 570° 1½ hrs.

15

45 lb. Muck (100 % to 25) to 1 qu.
then mixed some crude oil was added,
heated & well mixed,
Pressed but not very hard, could
be lifted.
It did not compress as much as
those without the oil,

Baked at 480°-500 1 hr.
Extremely hard & easily pressed
by a load of 15 lb, comes short —
Deduction — The oil causes
tighter, stiff, much sturdier more uniformly
over all formula, shape, moisture in formula
due to the oil ~~and left brown by evaporation of~~
~~the oil~~ #16

45 lb. (100-25 muck) to 1 qu.
Baked at 460° F 1½ hr.
Very good & hard briquette much
improvement over 12, 13 & 14 &
Good the alcohol test & was
all right throughout the whole briquette,

17 10/8/95

As to time, 100 hr. 25 minutes.

Briquette formed of first mixture (about 1 c.c. [illegible] oil) put on lift of briquette.

Coked at 400 to 500° for 1½ hr.

Briquette dropped 15 feet (tossed up) was not moved except to take a corner off.

Would say that this one was a considerable improvement over others of 12, 13 & 14.

Briquette was placed in ⊔ dish & left shape OK.

The 1 c.c. of oil may have acted in two ways, one causing the mush to flow & cement every contact point, the other by keeping other item fracture down around 450° for a longer period causing more iron resinate to be formed.

#18 10/9/95

Grain 100
Sand [illegible] from 1 lb in [illegible]) 40
French horse well stirred

Mixture made of above with 35 lbs per ton
Baked at 450° to 470° 1½ hr.
Briquette not very hard broke
in two when dropped 6 ft.
only very slightly softened by water.

#19

Mixture made with #19 mark
40 lb to ton.
Baked at 480 to 500° 1 hr.

20. 10/9/91 -

½ of a 45 lb ton (256100 mesh.)
briquette heated at 460°F 1hr
then 30 min at 500°F. (Burned too fast at a short time at first)
To see how much resin will remain or reinmate.

Wt of ½ briquette = 150.82

After baking wt = 149.15
Loss. = 1.67

% loss = 1.107

20.2 lbs to ton of ore remains.

21.

The other half of briquette used in #20 took 75 min to gelle 500°
heated at 500° for 30 min.

wt of briquette. = 149.53
147.9
1.63

% loss = 1.103

20.3 lbs. per ton remains after baking.

#21 & 20 were equally hard.

#22 12/9/41

Duplicate of #20 except temperature was run to 470° & held there 40 min: then to 520° & held there 40 min.

Wt of briquette = 148.15

" " after " = 146.98

1.17

% loss = 1.123

#23.

Duplicate of #21 except the heat was run to 520° & held 40 min.

Wt of briquette = 151.95

" " after " = 150.15

Loss. 1.80

% loss = 1.112

Experiments on Briquettes -

We have been using Muck consisting of 25 oil & 100 Rosin - Heating warm ore at the mixer so we could mix it. When the ore is 118 @ 120 we have no trouble in mixing this style of muck by the time the ore gets through the last mixer the ore is cold and can be squeezed into quite a hard ball in the hand it appears to be perfect for bricking but the bricks from the Machines were not very strong, breaking when dropped on the floor 15 @ 20 inches, Even after 24 hours they broke by dropping 2 feet, We attributed this to the fact that the springs on the Bricker machine plunger were made double length and consequently did not put enough ore into the mould to give proper pressure In fact the

pressure springs on the levers did not leave when making brix showing that bricks did not get enough pressure —

These bricks went through the new oven and were no good nearly every one broke at the delivery dump — I took one up to assay room and found that it was baked all right except 1/4" at center

Aylesworth determined the amount of muck per ton & found there was 23 lbs only. the muck feed not giving 30 as intended,

We now make a number of tests to determine the proportions (10) the proper formula for the muck the amount per ton and the effect of pressure more or less —

The first experiment is Oct 30 Room 100 used 30 lbs of this formula to the 1m

made four brick-

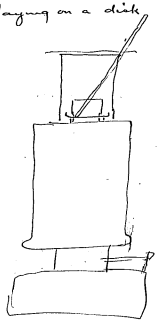
1st with light pressure in Vise.
2 with one turn more
3 " two " "

(10) The first one had the handle of vise turned so you could feel that the pressure was on & then it was given one complete turn, The 2nd brick was given 2 " turns & so on — 3 turns was the most pressure possible with jerking by one person.

The amount for each brick was weighed out to somewhat more than the regular brick being 320 grammes of ore, The resulting brick is say 1/4 to 3/8 higher than the regular size made by the machines —

These 3 brick varied in height after being pressed 1/16 inch between each other; between the 1st & 2nd it was probably a little more than 1/16 = We also made a 4th brick of the same ore which was allowed to get very cold outdoors & gave it the same pressure as No 2.

The bricks were then all baked in the Kerosene stove laying on a disk



The Thermometer also laid on the disk
The temperature were between 480 & 510
for one hour —

Results, No 1 broke when dropped on Table 3 inches above. Alcohol test showed it was thoroughly baked.

No 2 broke when raised about 2 feet.

No 3 " " " 3 feet,

Alcohol test showed they were all baked

No 4 acted just the same as No 2

One of the bricks made by the machine at the first test with new oven was baked also in kero stove, it broke in foot fall,

Same brick set inside of boiler door coundnt be picked up by hand after 50 minutes & when cool, the lefs was all out of it, This shows high heats are bad probably on account of oxidation —

2nd Experiment, formula 30 oil 100 Rosin, same as the first experiment but instead of 30 lbs per ton was used 40 lbs per ton and make 3 brick —

No 1 B one turn of vise handle
No 2 B Two " "
No 3 B Three " " the latter being
all cylinworth roof coved do —

We bake each 1 hour.

(Note = The one for one brick which we did not use but laying loose on the paper — cold had by its own weight got hard so pieces could be picked up = on squeezing in hand it made a very strong ball + appears fine for bricking although I think we shall have a little trouble with this proportion in feeding it to brickers —)
Except in very cold weather —

~~At~~ No 1 B with light pressure baked one hour, dropped 7 feet without breaking only an edge chipped off — had to ~~after~~ dropping it from 2 ft then 4 ft + then 7 ft a not breaking it I threw it up about 10 feet and it broke in 3 or 4 pieces but no fines to speak of. Alcohol test fully baked

No 2 B. - dropped it 7 ft didnt break then dropped it 10 feet didnt break only piece chipped off - Then threw it up 20 feet only broke off some more Edges had to throw it hard against the door & then it broke only in 2 pieces Alcohol test showed fully baked

No 3 B. dropped 10 ft didnt break or chip = threw up 20 feet didnt break or even chip threw it hard although it struck on stone lintel of door threw it hard against door didnt break, on second trial against door using more strength it broke in two parts with no fuses,

Took one of the pieces & threw it with great violence against door without breaking — Dont think Bricker machine could produce

Bricks with the pressure Cut
could easily produce those
as harder or harder than 2 B

3rd Experiment.

35 oil 100 Rosin —

30 lbs of mixture to the ton.

No 1 C is One turn of handle of vise
No 2 C " Two turns "
No 3 " Nearly 3 turns "

Notice that it finds its pressure quicker than either A or B experiments, which would show that it requires some power to force out through the filmes of mucl when stiff and Cold.
our Kerosene stove gave trouble & dont think the Baking on this experiment is correct Either with 1 C + 2 C = We did not watch stoves for 15 minutes & one got smoky & temp too low — The other one had also low temperature. but guess they will be Baked OK

No 1 C. dropped one foot didnt break - Broke at 2 foot,

No 2 C. Dropped 3 ft didnt break. dropped 5 ft didnt break, dropped 7 ft broke but only 1/3 broke off threw remainder up 12 feet it broke in several pieces =

No 3 C dropped 7 ft didnt break - dropped 10 ft Broken in half like this

945-

135-
6
810

500
175-

135-
5
675-

35-
7
245-
700

135-
7
945-

4th Experiment.

35 oil 100 Rosin -

Used 40 lbs to the ton,

No 1 D is one turn of vise
No 2 D is two turns of vise
No 3 D is 3 turns, as much as anybody could do by jerking

No 1 D dropped 7 ft didnt break - dropped 10 ft broke in two pieces

thus -

~~Thus~~
No 2 D dropped 10 ft didnt break - had to throw it up 20 ft & broke in 3 pieces

Test of viscosity of smoke mixtures.

Dec 8, 1897

The figure in circle or oval represents number of eighths of an inch on scale of testing machine passed in one minute by calculation based on number passed in a fourth of a minute.

The figure on right underneath is the inches on arm that weight is placed, on left underneath approximate reading.

20 oz. Brown
5 oz. oil — (51) 9" — 9 sec rising — 8½ minutes breaking — 8/9 .11
8-53 Am — 73°

20 oz Brown
8 oz oil — (41/2) 9" — 1-30 sec rising
Brown 82°
73°

20 oz Brown
8 oz oil — (?) 9" 2'20" breaking — 4 sec rising — 19/6 — 8.4
Brown 77°
73°
9-14-10

20 oz Brown
5½ oz oil — (66) 9" 3' breaking — 7 sec rising
73°
9-22-30

13
32
156

16
12
197

20 oz wain
6 oz oil
9-32-10

(120)
73° 9"

3-4 sec rising
1'30" washing

---

20 oz wain
8 oz oil
9-51

1 hour 175°
from 9/8/97

(156)
73° 9"

2 sec rising
50 sec washing

---

20 oz wain
6 1/2 oz oil
9-58-20

(197)
73° 9"

2 sec

---

20 oz wain
8 oz oil
10-41-40

Heated Dec 7 1 hour 325°

(10)
56° 9"

45 sec rising

Dec 9 1897

20 oz wain
8 oz oil

Heated Dec 7 1 hour 325°

(84)
75° 9"

19
6
84

---

20 oz wain
8 oz oil

1 hour 325°

(5)
74° 9"

(27)
74° 18"

---

20 oz wain
8 oz oil

from 175°

(264)
74 9"

22
10
264

---

20 oz wain
8 oz

3 hours 175°

(192)
74 9"

16
8
192

Rise in temperature

	18"	9"	50° 18"	9"
44°	228	56	384	108
	72	72		126
		14	96	28
	300	136	480	262
	150	45	240	87

150)240(1.6 .45)87(1.9
150 45
900 420

average 6)1.75 29% per degree

53° oil	9"	73°	9"
20 gr 8/20	6		66
6g	20		120
6/20g	48		197
	74		383

74)383(5.2 26% per dg
370
130

an increase of 1° increases fluidity 25%

25.5) 55 (21.6
510
400
255
1450

26) 6 (231
52
80
78
20

27.5) 75 (2 7.3
550
2000
1925
750

48) 8 (1
48
300

6) 20 (33

265) 65 (24.5
530
1200
1060
1400

27) 7 (258
54
160
135
250

28) 8 (28.6
56
240
224
160

78) 168 (2.2
156
120

168) 204 (1.2
168
360

33) 1000 (33

240
160
220
120
740
25) 185
74

Increase percentage of oil

20 oz min oil at $3				Percentage of fluidity
5 oz	=	25		
5½	=	27½	6	333
6	=	30	20	240
6½	=	32½	48	160
7	=	35	78	220
7½	=	37½	168	120
8	=	40.00	204	1073

25) 200 (8.0
25

an increase of 1% in oil increases fluidity about 75%

3° rise in temperature equals about increase of 1% or one part in oil.

[THIS BOOK WAS USED IN BOTH DIRECTIONS. THE FOLLOWING PAGES WERE FILMED FROM THE BACK END FORWARD.]

Anthracite Brick Fire

10.37		
10-40:24	270°	
10-41	285	22°
10-42	310 Drum	25°
10 43	330	20°
44	345	15°
45	358	13°
46	370	12°
47	382	12°
49	400°	

11-37 stop

#2 2 Anthracite bricks

11-55	2200	
57	265	22 1/2
12	310	15
2	321	10
4	345	8
6	364	9 1/2
9	380	7
10	390	5
15	4000	

12-55 stop

#3 2 anthracite Bricks

6 oz passed through 5 mesh
1 oz fines rolled twice
Heated to drive off moisture mixed barely warm

2-15	200° held at 210°		
2-18	213		
21	252	85	13°
27	337		14°
30	367		10°
36	389	22	3
38	395		
~~39~~	~~400~~°		

3-18 Strip

Did not crack

- Briquette good

#4 2 anthracite Pocket.
same as #3

3-31	2.15	
3-33	295	40°
-35	345	25°
37	385	
39	400'	

#-16 strip

Bonquette. good

	10-12	50	m 2 up	
	10-12	-20	m 2 on car	
	13	42	H	
	14	-10	m. 1 Down	
		20	" 1 C.D.	
35		55	" 7.D	
			m 2 7.D	
	15	10	m. 1 up	
			over	
		Wait for car		
		40	m. 2 C.D	
		55	" " 7.D	15
	16	5	" up	
		45	m. 2 O.C	
	16	50	m. 1 Run	
	17	20	" " Down	
		Rope caught on pulley		
	19	45	1 C.D	
35	20	20	1 7.D	5'-25"

		No. 1		No. 2	
		No. one	S.U	10 - 19-50	
			Down	20-35	
				wait Signal	
			C.D	21-20	
			F.D	-40	20
			O.C	22 15	
			S.U	22-30	
		39-30	Down	Mill shut down	
		45 10	CD	43-30	
	40	45-50	F.D	— -50	20
		47	O.C	44-30	
			S.U	45-50	
		49-45	Down	46-25	
		50-10	C.D	Wait Signal 48-45	
5'-25"	30	50-40	F.D	Pulling up 49-15	30
		51-25	O.C	50-30	
		52-20	S.U	51-15	
		53-20	Down	51-35	
3'-5"		Wait signal 54—	CD	-50	30
	55	54-55	F.D	52.20	
			O.C	53.5	
			S.U	54-10	
		56-50	Down	54-20	
				wait	

	No. 1		No. 2
	10-57-30	C.N	10-55 20
3'-20	30 58-	F.N	40 20
		O.C	56-40
		F.W	57-35
	11-12-50	Down	58-30
	13-15	C.N	No. 3. 59-1'
	35 13-50	F.N	Elevator XI, Stopped
	14-30	O.C	11-12-25
		F.W	11-13
	16-35	Down	Train stopped 15-10
3'-35	No. 2 17-	C.N	15-40
	50 17-50	F.N	-50
	19-25	O.C	16- 10
	19-50	F.W	16-50
	20-30	Down	17-25
	-35	C.N	18-20
3'-50	20 21-55	F.N	30
	23	O.C	50 20
	23-25	F.W	19-30
	24	Down	Water cups 24
			27-5

Rafter stuck 11-26		C, D	27-30
35	26-35	7, N	-50 20
	27, 45	O, C	28-30
Dispute about ship 1-6	30-10	S, N	29, 15
	31-40	Down	29-40
		C, D	45
Wire rope -45		7, N	30 15
wind on drum		O, C	30-40
		S, N	
		Down	
35	1-9-40	C, D	1-10-40
+	10-15	7, N	10-50
		O, C	11-20 30 +
	12-5	S, N	
	12-5	Down	15-50
	15	C, D	16-00
Crane rope back 15-25		7, N	16-20 20 +
+		O, C	17-
		S. N	
		Down	

No 1.		No 2
17-45	A	19
7-55	C.D	19-5
40	7.D	20
18-35		22-25
21-0	D	Train stuck Trolley
		25-50
-5	C.D	55
35	7.D	26-20
-40		23
No. one	Down	28-40
		50
	C.D	29-7
	7.D	17
32-10	Down	31
-22	C.D	31-12
		20
-50	7.D	31 32
26		wait for train
35-10	Down	33-25
		-30
-20	C.D	-48
		18
50	36-10	7.D
38-30	Down	36-45
		-50
35	C.D	
		18
25	39-0	7.D	37-8

40-57	D	39-25	
41+8	C,D	-32	
42-5	F,D	-45	13
	D	42-52	
No One	C,D	wall 43-15	
	F,D	-38	23
	Down	45-20	
	C,D	-27	
	F,D	-50	23
	Down	Rock on car in wrong place	
	C,D	46-10	
	F,D	48-6	
		-35	27
	Down	49 57	
	C,D	50 2	
	F,D	1- ~~50~~ 20	18
	Down	52 - ~~6~~	
	C,D	- 5	
	F,D	-25	20

# 1	# 2
35	15
35	20
40	20
30	36
55	30
30	20
35	10
50	20
20	20
35	15
35	30
40	20
35	20
28	25
50	17
25	20
58	18
40	18
60	13
	23
	23
	27
	18
	20
	20
	20
	19
	15
	25

19 | 73 6 | 38
-57
166

26 / 54 / 56 / 29

584

Down-	1-5 3-55
C.D	54-
F.D	54-20
1-57-27 Down	55-45
mark signals C.D	56-25
2-3-30 F.D	-45
10 3-10	2- 3-25
5-15 Down	Signal 4-6
Big rock -25 C.D	-27
50 6-25 F.D	
8-25 Down	7- 5
-35 C.D	-15
Roller fed 16-35 F.D	-30
+ 18-15 Down	14-45
-25 C.D	W.S. 15-20
+ Mill shut down F.D	-45
Down	
C.D	
F.D	

20 +

20 +

19 +

15 +

25

No 1		No 2
	Drum	[illegible]
	C.D	-30
	F.D	-50
9-31-20	Drum	30-15
Long [illegible] 38	C.D	-25
32-50	F.D	-45
	Drum	33-20
	C.D	-28
Paper twisted	F.D	-42
36-36 5"	Drum	35. 40
57-0	C.D	
-25	F.D	-36-0
40-00	Drum	~~[illegible]~~ -37-50
10	C.D	
Blot	F.D	[illegible] 35.35
10-7-55		43
10-45	Drum	10-8-40
-55	C.D	12 58
11-48	F.D	9-12
	Drum	light scraping engine loose collar
	C.D	cracked plate on
	F.D	intermediates

27'

3-46-15	Down	3-44-25
-25	C.D	-47
-45	F.D	45-3
	Down	47-10
D.7	C.D	-40
	F.D	-57
50.10	Down	49-25
Least original 3-50 50	C.D	-30
~~Last original~~ 51 15	F.D	~~-35~~
53-15	Down	51-33
-20	C.D	52-0
-52	F.D	52-20
55-55	Down	53-20
56-5	C.D	-30
-25	F.D	-55
58-40	Down	
-50	C.D	57-10
3-59-10	F.D	-25

No 1		No 2
No one	Down	3- 59-40
	C.D	50
	F.D	4-0-10
		several o/c/pas
4-12-55	Down	4-13-50
13-0	C.D	Until signal 14-25
-30	F.D	-45
15-45	Down	17-20
16-0	C.D.	30
Big hump		45
16:55	F.D	19-10
	Down	-20
	C.D	
19-50	F.D	
21-50	Down	20-35
22-5	C.D	-40
22 25	F.D	21.25
	Down	
	C.D	
	F.D	

12/8 97. Anthracite

8 Room 0g

32 water "

40 Pitch. gram

~~[illegible] 700~~

750 to 800 @ 2.00

~~[illegible]~~ @

[illegible] 600 [illegible]

[illegible] 850 .400

Pengwitte Little

Notebook, N-95-11-00

The two dated entries in this notebook are from November and December 1895. The book was used by Edison, John Ott, and an unidentified experimenter for notes and drawings regarding phonograph cylinder experiments. Also included are various other drawings relating to the phonograph and the electric light. Near the end of the book are several lists in Edison's hand of chemical compounds, possibly pertaining to x-ray experiments. The pages are unnumbered. Approximately 25 pages have been used.

Alloys used in expts. on
[illegible]

#1 - Fusible alloy -
50 parts Bismuth
25 " tin
25 " lead.
poured in a cold mould, turned off fine, fine, speaks good, no scratch -
was remelted + poured in a hot mould to prevent chilling.
Hot mould no good, metal crystalizes + scratches, recast in cold mould
Good

#2
Fahlum Brilliants -
29 parts tin
19 " lead
cast in a hot mould.
Better

#3

Analygam of Lepenitz's metal

Commin 3
tin 4
lead 8
Bismuth 15

after all is fluid + well mixed, add mercury 2, (the mercury should be heated to about 212° before adding + add hot)

This metal will not cast in moulds, the mercury + heavy metals settle to the bottom.

Move pan heated until most by all the mercury was dis-
filled off, then recast in a cold mould. metal very hot.

no good

#4

76 Parts lead
24 " Antimony
cold mould
no good

5-

24 tin
22 lead
6 antimony
cold mould
no good

6

2.9 tin
1.9 lead
.4 antimony
cast in cold mould
no good

V Nitrate Soda melts well but semi cryst. will do to mix.

Citrate Iron & Am. thick sol. viscous probably evap down to glass.

Calci palmitate Viscid stringy but brittle cold — scarcely melt.

Nitrate Calc. melts but not so clear as Nit. Soda but its tough on cooling a little will do to mix.

V Ammonium Citrate melts, ratio of crystallization goes off, good.

Ammon + Sodium Phosphate (Microcosmic salt) is glassy.

V Ammonium Sulpho Cyanate, little crystalline, fuzzy, varnish very good (probably poisonous).

Acetate of Lead
might be used for mixing

Ammonium Sulphate
useful for mixing

Tartaric acid good
glazing

Citric Acid good

Motor for Cylinders
for Dionographs

Tin 95 [illegible] 5

[illegible] Cadmium 10

[illegible] 5

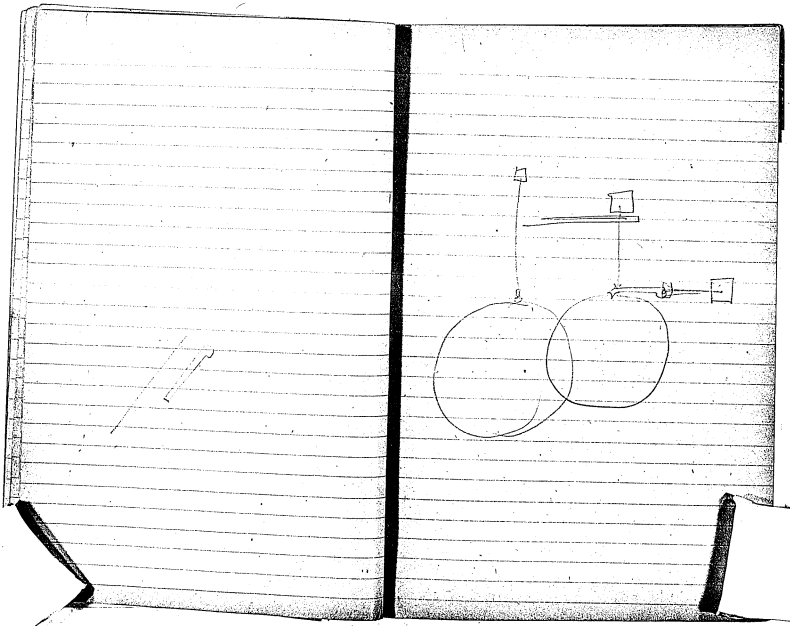
[illegible] 10

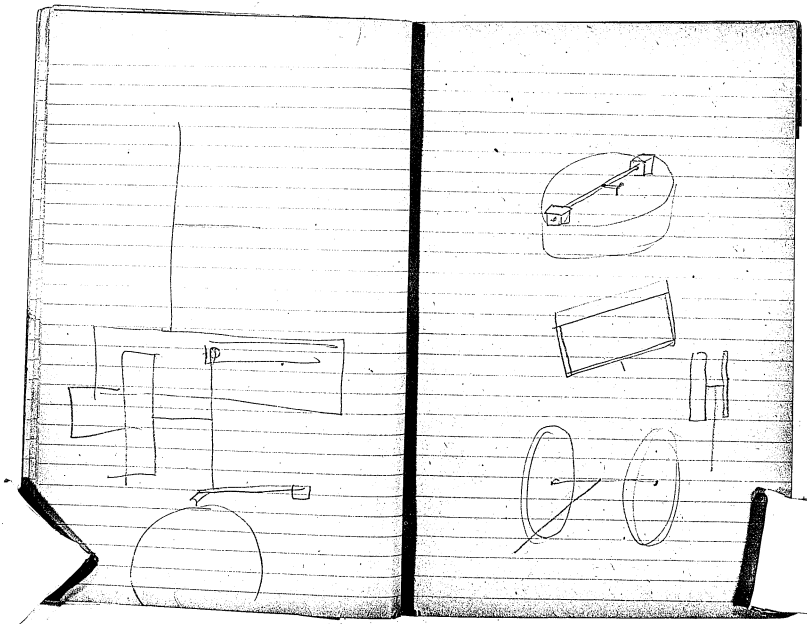
One Tin

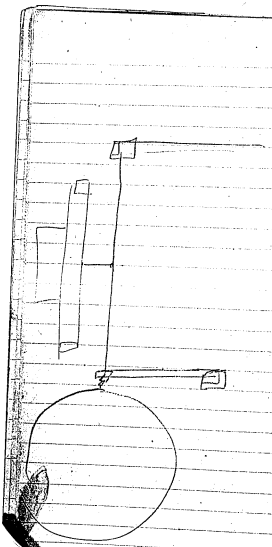
One Lead

One Brass

One Steel







J.E.O.M.

Leo 1895

Alloys for Phonograph Cylinders

Tehlum brilliant

Lead	19	8
Tin	29	12 1/2

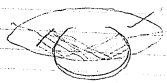
This turns very soft smooth and long fibrous

Looks fine clear and sheet

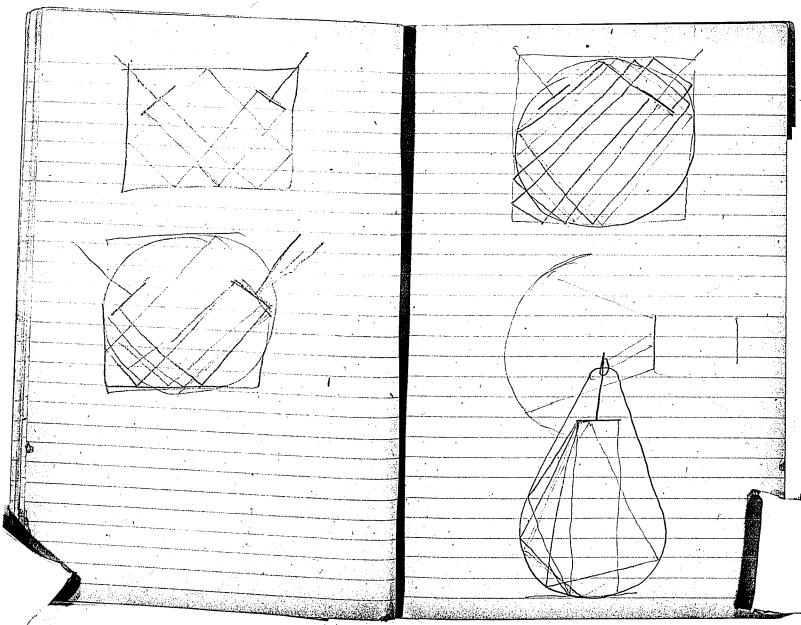
Lehrwitz? Alloy

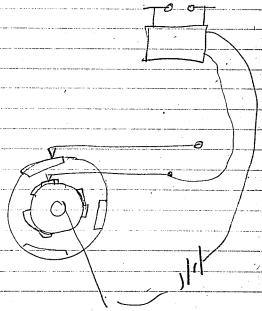
Cadimum	3	1
Tin	4	1.33
Bismuth	15	5
Lead	8	2.66

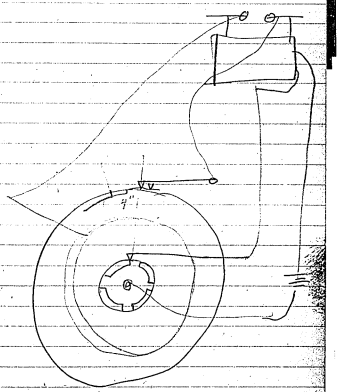
This turns soft but short grained looks fair



Old bulb 10 hours running over
5 days =



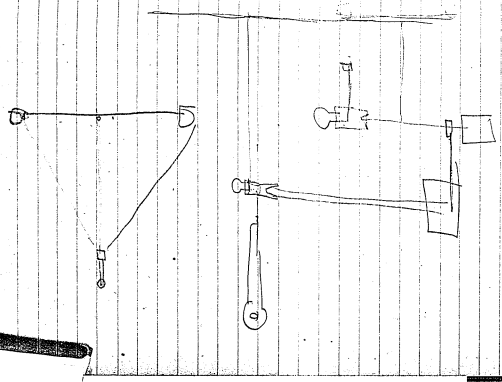




200

1500

350
900
1350
5000
350
7650
4
30,600
3



4

Uranium 1300 Acetate
phosphate
Sulphate
Zinc phosphate
1301 Acetate
1299 Chloride, aylsworth
1277 Carbonate
~~Nitrate~~
NO 35
43
49
79
92
100

No 2

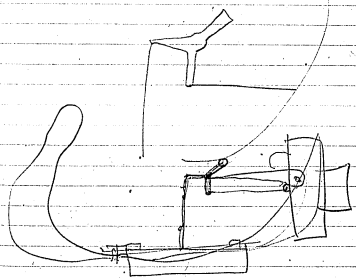
1209	Benzoate	Ammonium
1298	Fluoride	Barium
1279	Cadmium	Sulphate
1292	"	Bromide
765	"	Chloride
1291	"	Iodide ✓ Dup. No 1
1183	"	Bromate " " "
321	Calcium	Salicylate
259	"	Sulphurosum
		Iodide
		phosphate
1278	Iron	Dialised
1282	Iron	acetate sacc
1267	Lithium	Bromide Liq
	"	Benzoate
	Lead	Tannate
335	"	Iodide
7	Ammo "	Carbonate

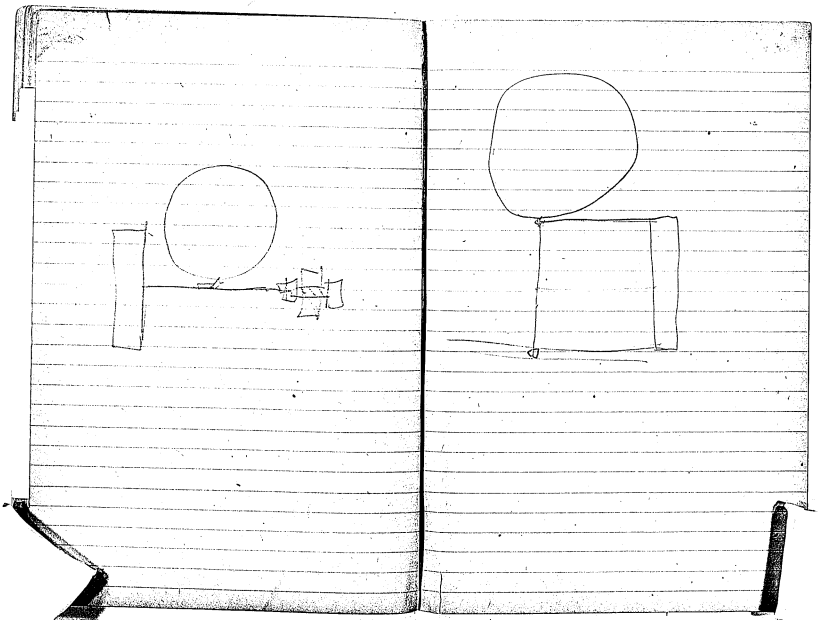
No 3

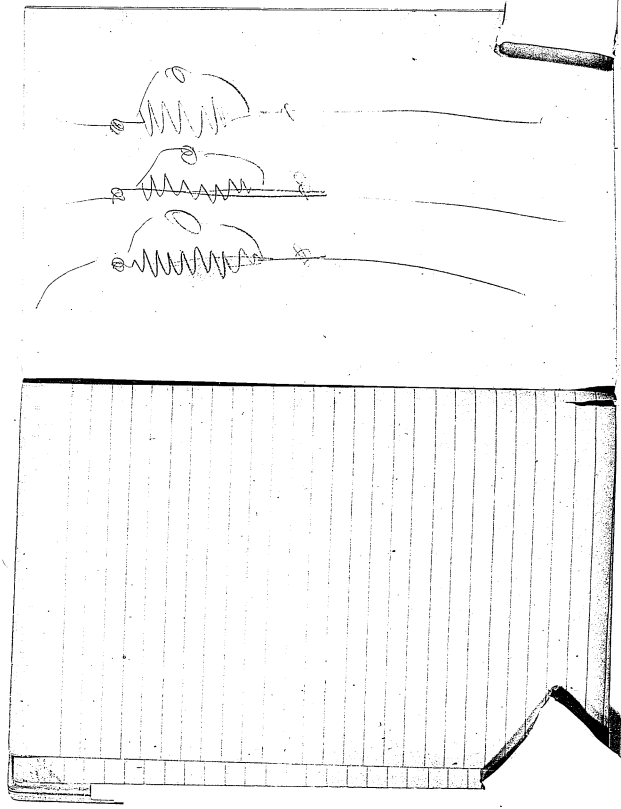
	Mercury	Bromide
1286	"	Subchloride
1284	Mercurous	Chloride
1272	Mercuric	Chloride
	Potassium	Salicylate
573	Silver	Chloride
	"	Carbonate
199	Sodium	Tartrate
1116	"	Cresotinate
1055	"	Salicylate
1195		Fluoride
1276		Bromide
574 - 760		Carbonate
813		Tungstate
1113	Strontium	Salicylate
191	"	acetate
1297	"	Chloride
		~~Tungstate~~
	"	Molybdate

No. 1

65 – Pectolite
107 Calcite
1260 Quicksilver Diphenyl
221 Natrium Arsenicus
576 Lead Sulphate
140 Ammon Salicylic
436 Cadmium Iodide
531 Tetra Meta Phosphate of lead
886 Na Chloride (Common Salt)
1183 Cadmium Bromate
8 Fluorite
1261 Calcium Tungstate
1263 Bromide of Potassium
1262 Iodide of Potassium
1264 Uranium Nitrate
1290 Lead Chloride
1288 Molybdic Acid







Notebook, N-97-12-15

This notebook, which is not standard sized, covers the period December 1897-February 1902. It is the second of three extant books used by Albert and Charles Wurth for notes regarding the electroplating of master molds for phonograph cylinders (see also N-91-11-24, Notebook Series; and "List of Moulds and Catalogue Numbers," National Phonograph Company Records, Company Records Series). Included are the names of the recordings that were used, along with the date of the plating. Some of the entries are listed as "Small Moulds for New Process Duplicates Speed 160." The front cover has a partially torn label indicating that the book was used as an exhibit in *National Phonograph Co.* v. *American Graphophone Co.*, Equity Nos. 1076 and 1103, United States Circuit Court, District of Connecticut. The book contains 180 numbered pages. Some of the pages contain tape and may be difficult to read.

Blank pages not filmed: 26-89, 178-180.

Date.	Name.	No.	Time.
1898.			
Dec. 1st	Dance of Arouseus Orch.	1.	
"	Standing on a corner Bob	2.	
	" " " "	3	
	" " " "	4	
" 4	Sleep my warm baby "	5	
" 4	Sally in our alley "	6	
" 4	Lady Betty "	7	
" 4	Lullaby from Carmen "	8	
" 9	Light of my life "	9	
" 9	Grace O'Mine "	10	
" 10	Take back your Gold "	11	
" 12	[illegible] "	12	
" 14	[illegible] "	13	
" 16	Half a dozen [illegible] "	14	
" 17	[illegible] "	15	
" 18	Seraph "	16	
" 19	Gabriel "	17	
" 23	[illegible]		
" 23	[illegible]		
" 25	Seraph Cornet	20	
" 25	Gabriel	21	
" 31	Laughing Irish W. Mullins	22	
Jan. 3	Returning Prince Orch.	23	
" 4	Hunting Girl W. Mullins	24	
		25	
"	Tell me not again Orch.	26	
		27	
" 10	Lohengrin Prince		
" 14	Seraph	28	
"	Serenade to the Angels	29	

Date 1898	Name		No.	Time
June 25	Serenade to the Angels	Clarinet	34	P.M. 2-00 5-
" 23	Tell me me again	Orch.	35	P.M. 4-20 6-
" 27	Twilight my own	Vocal Duet	36	P.M. 2-20 4-
" 28	" " "	" "	37	10-50 2
" 29	Attila	"	38	A.M. P.M. 10-20 2-
" 29	Arrival of the Bride	Orch.	39	P.M. 2-50 5-
July 5.	Carry Me Back to Old Virginia	Comp. by Prof. Bailey	40	P.M. 10-5 1-
" 5.	Dreaming my Dreaming	"	41	P.M. 2-10 4-
" 6.	The Crystal Fountain	Clarinet	42	9-30 11-
" 6.	Serenade	Mandolin Solo	43	3-15 5-
" 11.	Light Cavalry	Orch.	44	8-55 11-
" 11.	Artist's Life Waltz	"	45	1-10 2-
" 12.	Serenade to the Angels	Clarinet	46	8-40 11-
" 12.	Arrival of the Bride	Orch.	47	1-15 4-
" 15	Light Cavalry	"	48	7-20 11-
" 15	12 Variations	Clarinet	49	2-20 5-
	Second Platina			8-20 9-
" 20	Artist Life Waltz		50	10-20 2-
" 20	" " "		51	4-15 9-
" 21	" " "		52	11-15 2-
" 26	Suwanee River	Clarinet	53	8-45 10-
" 26	Arrival of the Bride	Orch.	54	1-40
" 29	" " " "	"	55	3-30 5-
X 29	Whistling Coon	W. Miller	56	3-30 4-
Aug. 1	Serenade Russe	Orch.	57	10-55
" 2	How d'ye my Gee	Mr. Bailey	58	11-30 4-
X 3	Laughing Song	W. Miller	59	11-15 4-
" 3	Suwanee River	Clarinet	60	11-15
" 6	Laughing Coon	Song	61	9-25
" 6	Whistling Girl	"	62	9-25
25	Laughing Song		63	11-
	Coon		64	11-
	Whistling Girl		65	

Date.	Name		No.	Time
Nov. 17-18	Lauderbach	Yodle Song	67	3-40 6-
" 21	Up Josh St. The Opera	Recitation	75	7-30 10 A.M. 8-30 12-
" 22	Whistling Susanna	Atelier	83	11-40 4-
" 25	Lauderbach	Yodle Song	67	9-25 3-5
" 30	Would I Were With The Whistling Coon		89	9-45 2-20
Dec. 1	When Will The Bride Come Back		91	9- Dec. 12-
" 2	Dixie Marvin Whistling Sol.		94	9- P.M. 5-55 9-00 A.M. P.M.
" 12	Peach of The Wheel Lilies	"	96	9-40 A. 2-
" 13	Old Kentucky Home	Clarinet	101	10-30 2-40
" 14	Tarriers Lieb (Collins)		99	3-10 5-
" 16	Down Suwanee River	Clarinet (Young)	60	10-40 2-

Machine #2.

Date	Name	No.	Time
Nov. 18	Doctor Chanlein Yodle Long	68	A.M. 7-30 7-50
" 21	Uncle Tromble in Hotel Receiver	76	P.M. 8-45 12-
" 22	Dew of the Morning	[illegible]	P.M. 1-15 4-
" 25	Chief, Chief, Polka Whistling	66-84	9-40 3-
" 30	Dolce Paine Polka Whistling	66-88	9-45 2-
Dec. 1	Ulmer's Lieder-[illegible]	" 91	9- 12-
" 12	[illegible], Chief, Polka Collins	66-97	A.M. 9-40 3-
" 13	Beautiful Dream Maid (Mellenaugh)	102	10-40 2
" 14	Where is Heaven	" 2	108 8-40 10-
" 14	Echoes of the Maine (Collins)	96	8-25 5-
" 15	Where is Heaven (Mellenaugh)	108	11-45 3-
" 16	Summer Dreams (Ackerind, Young)	66	10-16 2-

Machine #3

Date	Name	No.	Time
Nov. 18	Schneider's Lovers [illegible] out of Long	70	5-15 6-
" 21.	Uncle Tripp to Long & Reciter	77	A.M. 7-25 11-
" 22	" " at Stock Exchange	" 74	11-35 3-
" 25	Chief, Chief, Polka Whistling	66-84	7-25 2-
" 29.	Whistling Susanna	" 88	P.M. 2-35 7-
" 30	Bobolink	" 90	A.M. 5-15 10-
Dec. 2	Mocking Bird	" 95	P.M. 1-30 4-
" 12	Thoughts of a Sailor's Wife (Collins)	98	9-10 2-
" 13.	Song of the Soldier (Mellenaugh)	103	11-20 5
" 14	Whistling Pipes from Collins	96	11-30 5-
" 14	Because I love you Dear (Mellenaugh)	101	7-45 10-
" 15	Thoughts of Home (Ackerind)	42	2-30 4-

Machine # 4.

Date	Name	No.	Time
Nov. 17	Dr. Hunter Song with Song	69	5-6 P.M. 7-30 9-40
" 21	O Josh in a Shell Bar Recitn	73	9-35 12
" 22	" " arrival in N. York "	81	11-25 3-
" 25	Lullaby from Emmine Whiting Solo	86	2-45 5
" 29	Whiting Swanee "	83	5-45 P.M. 7-15 P.M.
Dec. " 30	Bobolink Whiting Solo	90	9-30 A.M. 10-15
Nov. 12	Fairies Frolic Allen Solo	99	9-40 3
" 12	Ah! Tell the Whole Tale Whiting & Shinn	104	11-20 3
" 14	Fairies Frolic Do Allen	99	10-35 3
" 14	Dreaming Sweet Dream (Mellowing)	107	4-30
" 15	Down in the Deep Cellar Chorus (Young)	100	2-35 4-40
" 17	Mr. Jasper's Wooing Whiting Solo	93	9-25 11-1

Machine # 5.

Date	Name	No.	Time
Nov. 18	Emmitts Duckworth Yodle Song	71	A.M. 9 12 M.
" 21	Oh Josh in a Dry Time Recitn	79	1-30 3-45
" 25	Lullaby from Emmine Whiting Solo	86	11-25 3-40
" 30	Whiting Gypsy " "	85	11-35 4
Dec. 1	Anvil Chorus (Young)	92	1-15 4-15
" 12	Down in the Deep Cellar Chorus	100	9-40 3

Machine #6.

[illegible] on #1 standard small

					A.M.	P.M.
Nov. 18.	Uncle Joshua Steel Bar Recitation	73	1b	10-30	2-	
" 21	U. Josh playing Ball "	80		1:30	3-	
" 25	Rocking Horse & Dove Whistling Solo	87		11-40	3-	
" 30	Whistling Bird Whistling Solo	85	1b	12-5	4-	
Dec. 1	Great Chorus " "	12		1-30	1-3	
Dec. 12.	[illegible] Home Clarinet Song	42		9-50	3-	
Dec. 14	[illegible] Kentucky Home Melodeon	107		10-	10-3	
" 15	Eldens Tabernacle " "	105	1b	10-17	3-	

Machine #7.

					A.M.	P.M.
Nov. 18.	Schneider Dance of arms Four Fells.	78	1b	9-50		
" 21	U. Josh. return to Farm Recitation	78		4	P.M. 12	P.M.
" 25	Rocking Horse & Dove W. Solo	87	1b	3-45	9-15	
" 30	Whistling Bird Whistling Solo	95	1b	12-45	6-	
Dec. 1	Mr. Jaffer's Shrill Whistle	93		3-30	Dec. 2 4-15	
" 12	Sunny Days Clarinet Chorus	3		11-5	3-15	
" 13	Eldens Tabernacle Melodeon	105		Dec. 14 8-	9-15	
" 14	Little Sleigh Bells (Chorus)	97	1b	1-10	4-10	
" 15	Song of the Rattler Melodeon	103	1b	10-	3-	
" 15	Old Kentucky Home Clarinet Song	101	1b	Dec. 15 10-5	3-25	5-35

Machine #8.

						B.M.T.	
Nov. 18.	Sleep, baby, sleep	Yodle Song	72	3-20	11-		
" 3	Yoho! Cabing	Fifth Ohio Bugle	82	4-	6		
" 22	Spring, Gentle Spring	Whaling Solo	84	5-			
" 30.	Warbling Bird	Whistling Solo	95	2-45	6-		
[illegible]	[illegible]	"	88	3-45	4-		
" 15	[illegible]	Fife O.K.	[illegible]	5-	8-		
" 13.	[illegible]	[illegible] (Medley)	106	2-50	4-		
" 14	Little [illegible]	Yodling	97	1-15	1-		
" 15	[illegible]	[illegible] (Medley)	102	1-10	3-		
" 15	[illegible]	[illegible] (Colored Young)	100	3-30			

Date	Cyl #	Name	Performer		T	B	Playing Master Time
1899 May 19	110 A.	Police Court	Col. Stuart	K	1/2	8	3 1/2 1-4
" 22	111 A.	Star Spangled Banner	Cadet Band	Cing	5/8	7	4 "
" 23	111 B.	" " "	" "	"	5/8	7	6 "
" "	1 C.R.	Dudley	Col. Vor		3/4	5	5 "
" 24	2 "	"			3/8	5	6 "
June 12	3 C.R.	Favor Fair Flowers	114		5/8	5	6 "
" 14	4 "	Daniel Boone	Vor		5/8	5	5 "

Concerts.

			No.	Time
July 6	(C) Promise Me	Carnfield	109	1-15 11-
	(B) League Carnf. Meeting	Band	12	1-15
" 6	Columbian Exp. March	"	2	2-30 11-30
" 7	" " "	"	2B	3-
" 7	Bredin Old Kentucky	Carnf.	110	3-15
" 10	Because	"	111	9-5 2-
" 10	Gro. Carnf. Meeting	Assoc.	50	4- 10-A.M.
" 11	Angelus Serenade	Orch.	13	1-30
" 12	" " "	"	13B	4-6 11-30
" 13	Long [illegible]	[illegible]	113	10 6-
" 14	Fields of Virginia	McD.	125	3-15
" 18	They Deceiver	Favor	113B	7- 12
~~" 18~~	~~Star Spangled Banner~~	~~Forgotten Word~~	~~Vor~~	~~8~~
" 18	Goodbye	"	114B	8- 6
" 19	Holy City	McD.	115	3-30
" 20	We Sat Alone There	Favor	120	2- 11-A.M.
" 20	Last Rose of Summer	McD.	116	9- 5-
" 21	Darkies Patrol	Assoc.	118	3-30
" 24	Because	Carnfield	462	-
" 24	Promise Me	"	111B	11-30 6-
" 25	Sunny Texas	"	109B	2-45
" 27	Goodbye	"	124	
" 28	Bred. Old Kentucky	"	111C	1-30
" 28	Just One Girl	"	110B	
			112	

Concerts.

1899.			No.	Time
Aug. 2.	Because	Camp.	111D	
" 3.	El Miserere	"	108	103
" 4	Because	"	111B	A=
" 4	Attila	Lyric Trio	84	
" 8.	El Miserere	Campbell	108A	
" 9	Just One Girl	"	112B	
" 10	Farewell my own	Trio	85	
" 14	Last Rose of Summer	McL	118B	1:30
" 15	Annie Laurie	Quartette	32	
" 16	Rocked in the Cradle	"	33	
" 17	Church Scene	"	34	
NG 19	"	"	34B	heard singing hard
NG 24	"	" .030	34C	rough
" 28	Rocked in the Cradle	Cor. Quartette	33B	Bad Cut
NG 28	Annie Laurie	.030 "	32B	Bad Cut
~~NG 11~~	~~Attila~~	~~Mould~~	~~118B~~	
NYG 11	Where is my boy tonight	McL	119	Crack
NYG 12	" " " "	"	119B	Crack
" 13	El Miserere	Campbell	108C	
" 13	"	"	108D	
" 13	"	"	108E	
" 14	Sunny Tennessee	Campbell	121A	
" 15	Coming Through The Rye	Tuson	57	
" 18	Ben Bolt	Tuson	56	
" 18	~~Comin Through the Rye~~	~~"~~	~~57B~~	
" 20	Ben Bolt	Tuson	56B	
" 20	Rocky Your Babe	Tur. Cut	24	
" 22	Dancing on the Housetop	C. O.	15	
" 22	Dinah Polka	Tur. Cut	26	
Oct. 2	Tattooed Man	Dudley	29	
" 2	~~Merry Widow Waltz~~	~~"~~	~~30~~	
	Merry Widow Waltz	"	28	
			28B	

Concerts.

1899	Title		No.	
Oct. 4	Yuba Dam	Dudley	164	
" 5	Sister Mary	"	30	
" 7	Green Fields of Virginia	McL	125B	
" 7	" " "	"	125C	
" 10	" " "	"	125D	
" 10	Holy City	McL	120B	Spoiled in Manufacture
" 11	" " "	"	120C	
" 11	" " "	"	120D	Spoiled in Plating
" 13	O Promise Me	Campbell	109C	
" 13	Bred in Old Kentucky	"	110B	
" 16	" " "	"	110D	
" 16	O Promise Me	"	109D	
" 17	Bred in Old Kentucky	"	110B	
" 17	Old Church Organ	C. Band	150	
" 19	Light Cavalry Overture	"	151	
" 19	Hoolahan Jawa	"	115B	
" 23	Old Kentucky Home	C. Quar.	196	
" 23	The Year	" "	35	
" 24	Old Kentucky Home	" "	196B	
" 24	Farewell My Own	Lyric Trio	85B	
" 26	Rocked in the Cradle	C. Quar.	33C	
" 26	Chopsticks Funeral	McL Cut	123	
" 28	Good-bye Sweet Dream	McL	121	
" 28	La Marseillaise	Band	172	
N. 31	In the Good Bye	Bye	11	
" 31	Stylia of Singing Penny		216	
N. 1	Sal from Sunnyside	Dudley	212	
" 1	Silver a Man	Nooley	87	
" 6	Pretty Little Queen Sola	Tuson	187	
" 6	Marcheuse	Bayes	Cornet	47
" 7	Bedouin Love Song	Nooley	86	
" 7	Fairy Queen of Yankee Band		236	

Concerts

1890

NG	Honolulu Cake Walk	Crosman	Orch.	242
" 8	Serenade March	"		49
" 14	Wm Tell Overture	Band		235
" 17	Smokey Moker	Banjo		186
" 14	Down to Georgia	Band		234
" 14	Cotton Blossoms	Banjo		188
" 15	Love in Tyrant	Camilla		269
" 15	Don't Do Anything Jenny			176
" 16	My Lady Love	Macdl		F281
NG	Stapelburg March	Band		274 A
" 21	Mean Thing Bird to Free	Quar.		266
" 21	Overture Don Carlos	Mel		270
" 22	Overture to Tancredi	Band		271
" 22	Barn Yard Medley	Quar.		190
" 24	Wilson Grove March	Band		279
" 24	Stapelburg March	"		274
" 28	Danube Waltz	"		276
" 28	Night Alarm	"		189
" 29	Good Bye the Sun Never Shines			283
" 29	Love in Hypnotism	Mel		122
Dec. 1	Break the News to Mother	Quar.		282
" 1	Benediction of the Pigeons	Band		275
" 15	Hickory Corner Church	Stewart		130
" 15	Chinese Laundry	"		295
" 16	Old Museum	Stewart		294
" 16	Daily Paper	"		296
" 17	Base Ball	"		124
" 17	Hickory Corner Church	"		130B
" 18	Daily Paper			296B
" 18	Chinese Laundry			295B
" 19	Baseball	Stewart		129B
" 19	Concertina of Everything	Lenny		176B

Concerts

1890

Dec. 2	Dinah Polka	E. Arch		26
" 2	Jerusalem Ventd Down	Quar.		283 B
" 15	Kentucky Babe	Quar.		214
" 15	Neighbor Party	"		290
" 19	My Creole Sue	"		267
" 19	Hush your noise	Heller		255
" 21	Lead Kindly Light	Quar.		306
" 21	Owl & Pussy Cat	"		305
" 26	Lead Kindly Light	"		306B
" 26	Weisbach Babe	Heller		160
NG	Honey House Ma Lady	"		161 Rough
Rosa	Dead Purpose Rough			
NG	Kentucky Babe	Quar.		214B Rough
" 17	Old Museum	Stewart		294B
Jan. 2	Ring on the Land & Sea	Broderick		D
" 2	The Red Scarf	"		E
" 3	Ring on the Land & Sea	"		D2
" 3	Love in Tyrant	Camp.		269B
" 4	Owl & Pussy Cat	Quar.		305B
" 4	Your fair Ch Than	Broderick		F
" 9	Beer Song from Martha	"		G
" 9	Absent Minded Beggar	"		H
" 10	Friar of Orders	"		I
" 10	Who treads the Path	"		J
" 12	Thursday	"		K
" 12	Song of the Turnkey	"		L
" 15	Vagabond	"		M
" 15	Tale of a Whale	"		N
" 16	Anvil Song	"		O
" 17	Absent Minded Beggar	"		H2
" 18	Eagle Song	"		P
NG	Minon Trust Sugar		crushed	287 NG

Concerts

1900

Ja V 22 Simon the Cellarer Ord. 2.
" V 23 Down at Lafferty's Cellar " R.
" V 23 Future Chorus " S.
V 24 Harbour of Lament " T
V 24 Rocked in the Cradle " U
V 25 Let Me Live " V
V 25 Since Thou art mine " W.
V 26 Call of Bold Lovers Manuico 314 X
V 29 El Cocoro Lorocks & Velo 307 Y
N.G. 30 Just Suppose Velo 192 Z
" V 30 Always " 192 Z
N. G. Cornfield Medley Ducas 197 Brooks
" V 31 Old Folks at Home " 308
Feb. G. Soldiers Farewell Madura 262
" V 2 Aveux de Printing Madura 258
" V 3 Come Home " 327
" V 5 Military Gulop Band 286
" V 3 Les Romeaux Bague 367
" V 5 Louisiana Lou Ducas 316
" V 7 Mirodiade French Bague 329
N. G. 7 Morning Dew to The Band 315
" V 7 Les Huguenots Bague 324
" V 7 Hello Ma Baby Band 322
" V 8 Christian Wally " 288
" V 8 Over to Bob's Pleasant " 328
" V 9 Heart Bowed Down Broder. 328
" V 9 Jolly Coppersmith Band " 326
" V 9 Bonda Wally " 307
" V 9 The Palms Broderick 307
" V 13 Just Suppose Velo 307
" V 13 Quien Es Alamo Franco 300
" V 14 Lovely Eternity Campbell 220
" V 14 Hush your noise Velo 307

1900

Feb 16 E.C. Cafe Puerto Rico Thomas 299
V 16 Yarn of the Plates Broderick 7
V 19 A Lost Love Campbell 222
N. G. La Cocina Francisco 318 Brooks
V 20 El Milagro " 320
2 V 20 Old Folks at Home Ducas 314B.
V 20 Always Velo 192B.
V 20 Creole Sue Ducas 267B.
V 21 Styles of Singing Denny 216B.
V 21 Merry Pieces of Window Band 236B.
V 26 Overture to Cavaleria Band 271B.
V 26 Picture No Artist Band 270B.
Mch 1 Sleigh ride Party Lund 290B.
V 2 Sonata at the Crystal Violin C.C.
V 2 Home Sweet Home " B.B.
V 2 Melody by Sarasate Violin A.A.
V 2 Rigoletto Violin D.D.
N. G. 3 Sons of Clifton Violin E.E.
" 3 Hungarian Dance Violin F.F.
V 5 2nd Mazourka Violin G.G.
V 6 Senza Tetto Italian Albertie H.H.
V 6 Prologue Italian " I.I.
V 6 Lo Filice " " J.J.
V 6 Chi Valor Canto K.K.
V 7 Alla Vita Italian Albertie L.L.
V 7 Barcarole Italian Albertie M.M.
V 8 Let Me Live Broderick V.
V 8 Melodiesy Sarasate Violin A.A.2
V 9 La Cocoro Albertie 110506 N.N.
V 9 Waltz by Chopin Violin O.O.
V 9 Old Black Joe " P.P.
V 12 Spanish Dance " Q.Q.
V 12 Serenade Violin R.R.

1900 Concerts

M.G.	2	Ion Ballou Mascher	Amirsed	R.A.
M.G.	14	Cornfield are brighter	Vidi Blick	G.C.
M.G.	14	Home Sweet Home	" Blicks	B.B.
"	4	Hungarian Dance	"	F.F.
"	3	2nd Mazurka	"	G.G.
"	6	Rocked in the Cradle	Curtis	II
"	18	Traverse Polka	"	III
"	19	Romance	"	IV
"	14	Le Petit Noel	V. Duett	V
"	20	Sea Shell Patty	Orchestra	
"	20	Grace Bonter	Alle V. Duett	VII
"	21	Blue Bells of Scotland	Orch.	VIII
"	22	Allegro	V. Duett	IX
"	22	Ida Taffet?	V. Duett	X
"	23	El Miserere	Orchestra	XI
M.G.	26	O Mio Babbino Caro	V. Duett	XII
M.G.	26	Ben Bolt	Piano Solo	
M.G.	26	Break the News	Quar.	
"	26	Minstrel Scene	Minstrels	37 XI
"	27	Pardonez Moi	V. Duett	XI
"	27	On a Bicycle	Stewart	293
"	27	Cornfield Medley	Quar.	197
"	28	Setting Tonight	"	3
"	28	El Miserere	Violins & Ullmann	331
"	28	Chimes of Trinity	Campbell	177
"	28	Battle of Manila	B. Orchestra	694
"	29	Niagara Jamaica	Ullmann	368
"	29	Imitation Bag Pipe	Ullmann	334
"	29	Sweet Magnolia	Quom Quar.	366
"	30	Soldiers Farewell	Quar.	308
"	30	Polish Mazurka	Violin	332
Rough		Then You'll Remember	Ullmann	369 XX

1900 Concerts

Wk.	1	At the Opera	Stewart	364 XXIII
"	2	Carnival in N.Y.	Stewart	363 XXIII
M.G.	3	Plantation Minstrel	Burnt	237 N.G.
"	3	Police Court	Stewart	383 XX
"	3	School House Director	"	378 XXIV
"	3	Street Car	Stewart	382 XXV
"	4	Minstrel Pot Pourri	Minstrels	204
"	4	Break the News	Quar.	282
"	5	Bonnie Lad are Brighter	Violins & Ullmann	336
"	5	March from Singing Girl	Orch.	335 7
"	5	Purdo Solo with	Orchestra	3
M.G.		Lively Minuet	Stewart	370
"	6	3 min with the Minstrels		206
"	6	Ben Bolt	V. & Ullmann	333
"	6	Lilli Dell'monico	Stewart	365 XXVI
"	6	Bunco Steerer	"	361 XXVII
"	9	The Society	Stewart	380
M.G.		Stock Exchange	"	128 M.G.
"	9	Circus	"	379 XXIX
M.G.	10	Imitation Minstrel		237
"	10	Campmeeting	Stewart	360 XXX
"	10	Department Store	"	126
"	11	Pumpkin Centre	A.R. "	362
"	11	Stock Exchange	"	128
"	12	Ninon	French M. Alba	XXVII
M.G.	12	Air L'Hamlet	" "	XXI
M.G.	16	Le Prouvere	M. Alba	XXXII
"	16	Contabilbed De Villers	Lagoner	XXXIII
"	17	5 Ave. Bus	Stewart	127
"	17	Things by Gounod	M. Alba	XXXI
"	17	Simon Fernand	M. Alba	XXIV
"	18	Le Prouvere	M. Alba	XXVI
"	18	Minstrel Pot Pourri		204

1900 Concerts.

Oct 14 The Troubadour Orchestra 230
" 14 From Belle to Belle - Band 373
" 20 La Secret Polka - Band 330
" 20 Mamiot March - Band 377
V 20 Torch Light Lance - Band 372
V 21 Hannah Lady - Band 374
" 23 Sel. Don Cesar - Band 375
V 23 At the Opera Stewart 364 B.
V 24 Loyal Legion March - Band 376
V 24 Mizpah Duett - Nelson & Alberti
NG 25 Because - Violin Allemaine Allemaine 335 Wash
V 25 Lilddio Duett M. Nelson & Alberti XXVI
" 26 Then You'll Remember Me Allemaine 367 B.
" 26 Picking a posy Duck Vocal Miss Holter XXVII
" 26 Creole Love Song Miss Ashton XI
V 26 Cut Hunting Song Mr. Holter XII
V 27 Patterson Fly Song Miss Ashton XII
N.G. 28 Aria from Toscari Alberti Duett XI
V 30 Campmeeting Stewart 360 B.
" 30 Martha Jane Green Collins 102
Nov G. 1 Bewitched from Rufus Whallen Rufus Orchestra 191
V 1 Signs of M.L. Stewart 398
" V 1 Fire Drill " 399
" V 1 Lightning Rod Lgt " 381
" V 2 Trip to Coney Island " 400
" V 2 The Spanish Question " 401
" V 3 Sel. from the Serenade Orch. 19
N.G. 3 Aria from Toscari - Alberti Barney 105
V 3 Pocahontas Lullaby Collins 101
V 7 My Hawaiian Lady " 265
V 7 Darktown is out " 268
V 9 Torch Light Dance Band 372 B
V 9 Heart Bound Quartette 88

Concerts.

NG 2 Bernice 335 - Leslie Ward
V 14 Flag & a Bird Harry 410
" 14 Sylvy Love Song " 415
V 16 Asleep in the Deep " 309
V 21 Air Hamlet - Mad. Alba XXXI
V 21 Hart Mad. 436
NG 21 Mathlee Mavourneen Harry 411 Pure Tone Band
N.G. 23 Whistling Rufus - Orch. 191
V 23 Wandering Boy Mad. 119
V 23 Love Lorn Lily Mad. 435 XLVI
V 24 Since that Day Mad. 434
V 25 Sel. from Tannhauser Band 149
V 25 Little Bit off the top Duett 208
V 28 I Left Because I had you 428 Pure Tone Band
NG 29 Old N. Hampshire Home Duett 426 Pure Tone Band
NG 29 Sweet Magnolias Duett 427
V 31 Shadow of the Miner " 424
Dec V 1 Tennessee Gamedown " 425
" V 1 Tarcoma Orchestra 437 D
V 2 El Cleno Francisco 11042 B
NG 2 Carry this mother Duett 423 Pure Tone
V 4 My Lady Love Quar. 417
" V 5 Moonlight on the Lake " 419
" V 6 Campmeeting Jubilee Quar. 418
" V 6 County Fair Quar. 422
" V 6 Carry me back to Va " 420
" V 7 Cold Feet Denny 441
" V 7 For Old Times Sake " 443
V 8 Whistling Rufus Orch. 191 B
NG 8 Charlatan Mech. Orch. 25 Denny
V 8 Battle of Gettysburg Band 10
V 9 Arrie in N.Y. Stewart 363 B.
NG 9 Am. A. Museum " 294 C

Concert

June 1 Chinese Laundry Stuart 295 C
" 12 Lily of Paper Stuart 296 C
" 12 Just When I Needed you Lenny 442
" 12 Man took a Girl " 218
" 13 Cloud Int - " 167
NG 13 Blue Danube Waltz - Band 152
" 14 Magnolia Waltz Song - Arion 455
" 15 Sit in My Happy Home Arion 264
" 15 Queen Spring Time - Ashton 456
" 16 Have Not Been - Quinn 210
" 18 My Money Never gives Out " 414
" 18 On Ben Franklin's Day Que 386
NG 18 Gentle Bright Girl Natus 433
" 19 Her Name is Rose " 429
" 19 Dry A Museum Sieve 294 D
" 20 Sounds Serene &c - Swift 42
" 20 Face Behind the Mask - Natus 432
" 20 Invocation - Bague 11065
" 21 Enchantement " 2855 11063
" 21 In Happy Moments - Swift 447
" 21 Dramatic Polka - Swift 446
" 22 Minon - Bague 11035
" 22 Arioso d'Hamlet 11063
" 25 Petal Rose of Red - Natus 431
" 25 Toreador Song - Bague 11032
NG 26 Come Ye Faithful - Allen 450
" 26 Raffa Swatina " 449
" 27 Wandering Boy - Mach 119 D
" 27 O Mon Bernard - M. Alba 11061 B
" 28 Rocked in the Deep - from 413 B
" 28 Romanza - from 340 B
" 29 L'Ebro - Alberti 11056 B
" 30 Barcarole 11053 B

Concert

July 2 Cuterose Polka - Tromm 391 B
" 2 Il Balio - Alb & Noldi 11047 B
" 2 La Vile Nalty - Tromb & 405 B
" 3 Miserere - Alberti & Noldi 11057 B
" 3 Brunette - Alberti 417 B, 11058
" 5 Minon - Alb 11062 B
" 5 Rosamond - Stanley 96
" 5 Marching Thro - Tro " 174
" 6 Innocent Young Maid " 454
NG Sunday Sally - " 3 Stanley
" 9 Lamplighter - Quar 418 B
" 9 Sol Dom Carlo - Band 418 B 37 B
" 10 Advice to Men - Tenn. 199 Repeat
" 10 Klondike " 200
NG 10 Paris Exposition - " 466
" 11 Tune on G Washington Arion 467
" 11 Echoes of Minstrelsy 205
" 11 Schultz on Malaria - Tenn. 469
" 11 Minstrel Isl. Park A 460
" 12 Berceuse de Jocelyn - Bague 11069
" 12 Come Ye Faithfull - Allen 450
" 13 La Veuve d'or - Bague 11067
" 13 Lucia de Lammermoor " 11067
" 14 Attacked by Mosquitos Stanley 465 XXVII
" 16 Blue & the Gray - Harlan 461
NG Mr. Conductor " 463 Repeat at edge
" 16 Will Sing My Mama " 462
" 17 La Favorite - Bague 11064
" 17 Sunday Sally - Stanley 453
" 19 Blue & Gray - Band L1 471
" 19 Hands across the Sea " 138
" 19 Moonlight on the Lake - Quar 419 B
" 19 My Lady Love - Quar 419 B

Concert

1900

July 20 Ma Charmante Heyck Campo 11073 LII
" 20 Romance de Sommeil " 11071 LIII
" 21 La Marseillaise - Campo 11072 LIV
" 23 Air de Vulcain - " 11070 LV
" 23 Advice to Men - Kennedy 199B
" 23 Romance de Sommeil - Campo 11071 LIII
" 24 Haff Hagain Dixie Kylo LVI 474
" 24 Cradle Polka - Xylos LVII 473
" 24 Echoes of Minatrelsy 205B
" 25 Minatrel Ish. Park 460B
" 26 Pickaninny Polka - Xylo LVIII 475
" 26 Dancing on Housetop - Arch 15
" 26 Little Serenade - " 22
" 27 Dancing in the Sunlight - Xylo 476
" 27 Whif Poor-will - Belmont 388
Aug 2 Carrie Waves - Belmont 477
" 2 Old But Tough - Stewart 479 LX
" 3 There Aint a Word " 480 LXI
" 4 Napholitan Serenade Campo 11076
" 4 Chanson a Boire " 11075
" 6 Air du Cardinal " 11077
" 7 Off to Camp Band 4
" 7 La Serenade de Schubert Campo 11078
" 8 Court of Honor Mch Band 470
" 9 Star Spangled Banner " 171
" 9 Air de Figaro Campo 11074
" 9 Sel from Bohemian Girl Band 5
" 11 On the Levee - Band 472
" 13 Whistling Girl Johnson 484 LXII
" 13 Laughing Coon " 483 LXIII
" 13 Whistling Coon " 485 LXIV
" 14 Laughing Song " 482 LXV

Concert

1900

Sept 3 Wachtam Rhein - Dencing ~~298~~ Tulsa 11026
" 4 Hannal Lady - Band Expr.
" 5 Das Deutschen Vaterland - Dencing 1079
" 5 Schultz at Delmonico - Kennedy 468
" 13 Schultz on Washington " 467 Crescilia
" 13 Ave Mer 11080
" 15 Three Little Owls - Stewart 481
" 15 Edelweiss - Dencing 11081
" 18 Spring Song Waltz Arch 248
" 18 Love Lost Lily - Mch Coffer
" 19 Lady Lou Medley - Arch 257
" 19 March from the Lancers " 491
" 21 Hello Ma Baby - Collins 103
" 22 J. P. U. U. 99 Thresda X
Oct 16 Kathleen Mavourneen 100 4118
Nov 16 Little Nickaiea 98 2/3 The J. W. A.
Dec 27 Whistling Girl Johnson 484B
" 27 Ave Maria Stewart Coffer
" 29 Wedding Bells " 365B
1901
Jan 19 Laughing Coon Johnson 483B
" 10 Lightning Rodelgerch Saw Coffer
" 14 Fire Department Stewart 399B
" 25 Whistling Coon Johnson 485B
" 31 Laughing Song " 482B

Regulars.

1900.

April 14	At The Circus	Stewart	3883
" 14	Trip to Boston	Stewart	3885
" 23	Camp Meeting	Kennedy	3842
" 23	At Church	Kennedy	3833
" 24	Turkey in the Straw	Golden	4011
" 24	Holy City	Mack	2018
" 26	Australian N.Y.	Stewart	3875
" 26	Selection	Martha Band	79
" 27	Cornfield	Quar.	2204
" 27	Camping Jubilee	"	2226
" 30	Sunny Southern Home	"	2233
" 30	Serenade from Lucia	Band	88
May 2	Cornfield	Quar.	2204
" 2	Street Car	Stewart	3876
" 3	Trip to Farm	"	3880
" 3	Old Folks at Home	Quar.	7342
" 4	Call Bicycle	Stewart	3885
" 4	Spanish Question	"	3897
" 7	Holy City	Mack	2018
" 7	Turkey	Golden	4011
" 8	Church Scene	Quar.	2234
" 8	Ei Miserere	Allmann	7324
" 9	Minnesota Jamboree	"	7423
" 10	Kentucky Home	Quar.	2223
" 10	Base Ball	Stewart	3881
" 12	School Director	Stewart	3891
" 14	Mary Lee	Campbell	7287
" 14	Sabbath Day	Quar.	2204
" 16	Coney Is.	Stewart	3871
" 16	Chinese Laundry	"	3863
" 16	Whistling Rufus	Cox & Cohan	
" 23	Farmyard Med.	Quar.	2237

Regular

1900
Mar 22 Limited Express - Orch. 650
" 22 Whistling Rufus - Lucas 704
" 23 Church Scene - Lucas 2224B
" 23 Pretty Little Queen - Crimen 7264
" 23 Wedding over the hill - Golden 4015
" 24 Reception Medley - Quam 2206
" 24 When I was a lad - Trio 4807
" 24 Camp meeting - Stewart 3896
" 25 Andante - Violin Stage 7194
" 25 Picture No Artist - Camp. 7331
" 25 Auld Lang Syne - Quam 2203
" 29 Bumoe Steers - Stewart 3900
" 31 Bercuse - Camp Hall 5710
" 31 Police Court - Stewart 3895
" 31 Mr. Word is just as good - Camp 7405
Apr 1 A dream of a dead - Camp 2023
" 1 Hickory Corner Church - Stewart 3893
" 1 At the Opera - " 3871
" 4 Stop that knocking - Tiff 2024 2224
" 4 Rabbit Hash - Golden 4014
" 4 Wm. Mudd - Tiff 4025
" 5 Stop that knocking - " ~~2024~~ 4024
" 5 Yaller Girl - Golden 7202
" 5 Medley of coon Songs - " 4006
" 6 Ard Bun - Stew 3883
" 6 Sights of N.Y. - " 3882
" 6 Trouble in a hotel - " 3886
" 7 Bell Tri - Trio 4805
" 8 Deft Store - Stew 3879
" 8 Umbrella in the dogs - Trio ~~4806~~ 4806
" 11 My Susanna Banjo + Vio. Jno. A.
" 11 Just like a Girl - Denn 1910
" 11 Coming to the Old Home - [illegible]

Regular

June 12 Bye Bye Ma Honey - Gr. 4001
" 12 German 5 ts - Tiff 7304
" 13 Roll on de Ground - Golden 4010
" 13 Dim a dude - Tiff 7130
" 13 Mixed Ale Party - Golden 4007
" 15 Uncle Sam To Geo - Stew 7252
" 15 Uncle Jefferson - Golden 4003
" 15 Little Black Me - Camp 7416
" 18 Kings Highway - Camp 5701
" 18 Olcotta Fly Song - " 2038
" 19 And the Parrot Said - Denn 7127
" 19 Old But Tough - Stew 3903
" 19 Church Scene - Lucas 2224C
" 20 Mocking Bird - Golden 7169
" 20 Wont You be My Girl - Camp 5708
" 20 There Ain't A Word - Stew 3904
" 22 Laughing Song - Johnson 4004
" 22 Laughing Coon - " 4005
" 22 Whistling Girl - " 4013
" 25 Close Quarters Back to Back - Quam 2222
" 25 Whistling Coon - Johnson 4012
" 26 Dante Museum - Stewart 3889
" 27 Lightning Rod Ugly - " 7333
" 28 Stock Exchange - " 3887
" 28 Our Society - " 3894
M. 28 Pumpkin Eater ~~Stewart 7392~~
" 30 Julia Wedding Dance - Gr. I 4011
" 30 Suwanee River - Cornet III 9010
" 30 Hands across the seas - Gr. II 9010
July 2 ~~26~~ Chimes of Trinity - Camp 5700
" 2 Girl of Lorelei Lake - Denn 5718
" 3 Isabella Brown - Columbia Orch. IV 904
" 3 Colors of Mantle - [illegible]

Regular.

July 6 Moth-eth Flame- Camp 5719
" 5 Plantation Minstrels — VI
" 6 Sweet Magnolias- Camp 7224
" 6 El Moorse " 1571
" 6 Pumpkin Centre Rifl. Steu 3892
" 9 He Certainly Was Good-Lotin 5745 VII
" 9 Bred in Old Kentucky- Camp ~~VII~~ 5715
" 10 Cornfield- Lucas 2204
" 10 Sweetest Story- Camp 1575
" 11 Louisiana Lou- Camp 1523
" 11 Whistling Girl- Johnson 4013 B
" 12 Goodbye Sweet Heart- Camp 5711
" 12 As Your Hair Grows Whiter 1562
" 13 Light of my Life Camp 2029
" 13 Lil Mitchie your dear away 1565
" 16 Bocquet- Allmann 7420
" 16 Stock Exchange Steu VIII
" 16 Troubles in Holie " IX
" 18 Al Delmonico " 3890
" 18 Blue & Grey - Harlan 7433
Sept 1 Gramd - Sweet - J.H.O. X 90 Troops from 05
" 17 El Mississippi Allmann Copper
" 21 Spanish Question Steu Copper
Oldtz High School Leader Band Copper
" 29 Willie Polka- Band "
" 30 Harrison Bold Hooley "

Regular.

For Spec. Duplicating

1900
Dec. 26 N. Mrs Jady Luck Mach. 7342 A
" 26 " " " Mach. 7342 B

E.F.V.

30632

33-65

97

Small Moulds for New Process
Speed 160

Duplicates

1901				Blu. No	Sub No	S.No.	Cat. No.
Jan 21	All Coons Look Alike	Collins Banjo Acc.		1	7317		
" 21	Farmyard Medley		N.G. Quad.	2	2229		
N.G. 21	Popo's Recollections	Hohnmann Banjo Acc.	N.G.	3	7665		
N.G. 21	Old Oaken Bucket	Quad.	N.G.	4	2216		
" 22	Ach what a Cat	"		5	7531		
" 22	Please My God	Collins Banjo		6	7267		
" 22	All Coons Look Alike			1B	7317B		
" 22	Cornfield Medley	Quad.		7	2204		
" 22	Farmyard Medley	"		2B	2229B		
" 22	Cornfield Medley			7B	2204B		
" 23	Old Black Joe	Collins Banjo Acc.		8	7484		
N.G. 23	Cornfield Medley	Quad.		7C	2204C		
" 23	All Coons Look Alike	Collins Banjo		1C	7317C		
" 23	Cornfield Medley	Quad.		7D	2204D		
" 23	Please My God	Quad.		6B	7267B		
N.G. 23	All Coons Look Alike	Collins Banjo	N.G.	1D	~~7317D~~		
" 23	All Coons Look Alike	"		1E	7317E		
N.G. 23	Old Oaken Bucket	Platinum Cyl.		4B	2216B		
Feb 1	Warrior Bold	Copper Cyl.	Hockey		~~Cyl.~~		
" 1	Light Cavalry Over	E. Orch.		9	524		
N.G. 1	Behind the Gun	"	N.G.	10	7422		
" 1	" " "	"		10B	7422B		
" 1	Echoes of the Forest	E. Orch		11	527		
" 2	Narcissus	E. Orch		12	587		
" 4	Narcissus	E. "		12B	587B		
" 4	Narcissus	E. "		12C	587C		
" 4	Star of Liberty	E. Orch.	N.G.		7674		
" 4	Jolly Fellows Waltz	"		14	7341		
" 5	Jolly Fellows Waltz	"		14B	7341B		
" 5	Narcissus	E. Orch.		12D	587D		
" 5	Echoes of the Forest	"		11B	527B		
N.G. 5	Behind the Gun	E. Orch.	N.G.	10C	7422C		
" 5	Jolly Fellows Waltz	"		14C	7341C		

1901				S.No.	Cat. No.
Feb 19	Wine Women & Song	Orch		15	634
" 19	Rendezvous Waltz	"		16	682
" 19	Star Strike Mch.	"		17	621
" 19	Nobody's Boy Mach.	"	N.G.	18	7533
" 19	How to Bring up Children	"	N.G.	19	7434
" 19	Schultz on Conference	"		20	7477
N.G. 19	Schultz Advice to Mn.	"		21	3830
" 20	Schultz Advice to Men	"		21B	3830B
" 20	Stars & Stripes Mch.	Orch		17B	621B
" 20	Wine Women & Song	"		15B	634B
" 20	Rendezvous Waltz	"		16B	682B
" 20	Schultz Advice to Women	"		22	7487
" 21	Stars & Stripes Mch.	Orch		17C	621C
" 21	Schultz on Washington	"		18B	7533B
" 21	Schultz Advice to Women	"		22B	7487B
" 21	Schultz Advice to Women	"		22C	7487C
" 25	Wallatan Mch.	Orch		23	687
" 25	Hands Across the Sea	"		24	708
" 25	Floradora March	"		25	7725
" 25	Floradora March	"		25B	7725B
" 25	Chalatan March	"		23B	687B
" 25	Waltz from Fausk	"		26	631
" 27	Battle of Manassas	"	N.G.	27	663
" 27	The Mosquito Parade	"	N.G.	28	7503
" 27	The Mosquito Parade	"	N.G.	28B	7503B
" 27	Waltz from Fausk	"		26B	631B
" 28	Hands Across the Sea	"		24B	708B
" 28	Jolly Fellows Waltz	"		14D	7341D
" 28	Chalatan March	"		23C	687C
" 28	Mosquito Parade	"		28C	7503C
Mch 1	King Cotton March	"		29	561
" 1	Apple Dame	"		30	7616
" 1	Wedding Ring	"		31	7[illegible]

Small Moulds for

1901 Speed 160

March	My Lady Lou	Mel D & Orch.	32	N.9	7342
4	Maryland	"	33		2033
4	My Lady Lou	"	32B		7342B
4	Wine Women & Song	Orch.	15C		634C
4	Man Behind the Gun	"	10D		7425D
15	Whistling Rufus	Orch.	31B		704B
15	Lullaby from Elmira	Mel. D.	34		2030
15	Ainday-oua Valley	Orch.	16C		6829
15	King Cotton March	"	29B		5618
16	King Cotton March	"	29C		5616
	~~Whistling Rufus~~	Orch.	~~31C~~		~~704C~~
16	Maryland	Mel D & Orch	33B	N.9	2033B
18	Wandering Boy	Mel D & Orch	35		1539
19	Sweet Bye & Bye	"	36		2021
20	Lost Chord	"	37	N.9	6504
20	Holy City	N. Orch	38		2018
20	Almost Persuaded	"	39		2003
20	Safe in Arms of Jesus	N.9	40		1539
21	Safe in Arms of Jesus	"	40B		1539B
21	Wandering Boy	"	35B		1539B
21	Lost Chord	"	37B		6504B
21	Holy City	"	38B		2018B
22	Sweet Bye & Bye	"	36B		2021B
22	Holy City	"	38C		2018C
22	Sweet Bye & Bye	"	36C		2021C
23	Fortune Teller Waltz	Orch.	41		698
25	Red Rose of Summer	Mel D.	42		1521
26	Magnolia Bloom	Mel. & Har.	43		7475
26	Babya Prayer	Dodd	N.9	44	7540
26	Left Breakfast Love you	"		45	7498
26	Leave Came Down	"		46	7382
27	Babya Prayer	Dodd		44B	7540B
27	Magnolia Bloom	Dodd		43B	7475B

New Process Duplicating

1901 Speed 160

March 27	Leave Came Down	Har. & Mel.	46		7382C
27	Leave Came Down	"	46		7382D
28	Shadrach	by the Swanee	Natu.	47	7495
28	Where the Miss. Flows	"	48		7741
28	Day by Day	"	49		7732
28	El Miserere	"	50		~~15118~~
29	Shades of the Pines	M. & H.	51		7347
29	Freedom & Ireland	Nature & Orch	52		7627
30	Day by Day	Nature & O.	49B	N.9	7752B
30	Sweet Antoinette	M. & H.	53		7603
April 1	El Miserere	Nature & Orch.	50B		15118
1	Day by Day	"	49C		7732C
1	Where the Miss.	Day by Nature	48B	N.9	7741B
2	Fortune Teller	Waltz Orch.	41B		698B
2	Shades of the Pines	M. & H.	51B		7347B
2	Freedom & Ireland	Nature & O.	52B		7627B
3	Where the Miss. flows	Na. & Orch.	48C		7741C
3	Freedom & Ireland	"	52C		7627C
3	El Miserere	"	50C		15118C
3	Spirit of Liberty	Orch.	13B		7474B
4	On Duty March	Orch	54		7704
4	Barn Dance	N.S.	N.9	55	7725
4	Knighthood in Flower	"	56		7773
4	"	"	56		7773A
5	"	"	56		7773C
5	Joys Quiller	"	57		7805
5	On Duty March	N.9	54		7704B
5	Joys Quiller	"	57B		7805B
8	Freedom & Ireland	Nat. & Orch.			7627D
8	Babya Prayer	to M.	44C		7540C
8	"	"	44D		7540D
8	Knighthood in Flower	Orch.	56B		7773B
9	Leave Came Down	N.9	46B		7382B

7382 D Dated June 9th above glass

1901

Apr. 9	Lullabye from Ermine Mell+Co.	34B	2030B
" 9	Schultz on Temperance-Ker	20B	7477B
" 9	How to Bring up Children-Ke	19B	7434B
" 10	Mosquito Parade Or.	28D	7523D
" 10	Echoes of the Forest "	11C	527C
" 10	Waltz from Faust "	26C	631C
" 10	Lullabye from Ermine Mell	34C	2030C
" 11	Trip to Farm Stewart	58	3880
" 11	Game of Baseball "	59	3881
" 11	Game of Baseball "	59B	3881B
NG.	Game of Baseball NG. (Washington)	59C	3881C
" 12	Game of Baseball "	59D	3881D
" 12	Trip to Farm "	58B	3880B
" 12	Dep't Store "	60	3879
" 15	Arrival in New York "	61	3875
" 15	Street Car "	62	3876
" 15	Arrival in N.Y. "	61B	3875B
" 15	" " " "	61C	3875C
" 15	Trip to Farm "	58C	3880C
" 15	At The Opera "	63	3877
" 16	Street Car "	62B	3876B
NG.	Coney Island " " (Gold Dust)	64	3878
" 16	Coney Island " "	64B	3878B
" 17	Signs of New York "	65	3882
" 17	" " " "	65B	3882B
" 17	" " " "	65C	3882C
" 17	At The Opera "	63B	3877B
" 18	At the Museum "	66	3889
" 18	Arrival in N.Y. "	61D	3875D
" 18	Street Car "	62C	3876C
" 18	Street Car "	62D	3876D
" 19	Stock Exchange "	67	3887
" 19	Stock Exchange "	67B	3887B

1901

Apr. 19	At The Museum-Stew	66B	3888B
" 19	At The Circus "	68	3888
" 22	At The Circus "	68B	3888B
NG. 22	At Delmonicos " (Cracked)	69	3890 NG.
NG. 22	At Delmonicos " NG.	69B	3890B
" 22	At Delmonicos "	69C	3890C
" 23	Shine-Sojer Man NG. Stew	70	7733
" 23	Shine-Sojer Man-Du	70B	7733B
" 23	Eric Mac Eulee NG.	71	7796
NG. 23	Oh Oh, Miss Chock-NG.	72	7762
" 24	School House Lir-Stew	73	3891
" 24	School House Lir "	73B	3891B
" 24	Trip to Boston "	74	3885
" 24	Trip to Boston "	74B	3885B
" 26	Eric Bus "	75	3883
" 26	Eric My Eulee NG. Du	71B	7796B
NG. 26	Wait Stew Orch (Dark)	76	7689
" 26	Wait Stew Orch	76B	7689B
" 26	Wait Stew. Orch	76C	7689C
" 26	Eric My Eulee Du	71C	7796C
" 29	Tobie Collins & Piano	77	7790
" 29	Vaudeval NG.	78	7823
" 29	Sunday Sally-Stew	79	7802
" 29	Mum Behind the Sun "	80	7802
" 29	Pliny Co. & Pia.	81	7762B
" 29	Bushes Stew	82	3900
" 29	Police Court "	83	3895
" 30	Star Spangled Banner Stew & Co	84	3904
" 30	Tobie Co. & Pia.	77B	7790B
" 30	Pumpkin & R.R. Stew	85	3892
" 30	Trouble in Hotel "	86	3886
May 1	Star Spangled Banner Stew & Co	84B	3904B
" 1	Bus Bijou Stew & Co	87	3913

33 - 224

1901				
Mch 1	Police Court	Stev	83B	3895 B
1	Man Behind the Gun (Stan + Co)		80B	7802 B
1	" " " " "		80C	7802 BC
2	Bicycle	Stev	88	3898
2	Compromiting	"	89	3896
2	Dept Store	"	90	3790 C
2	Baptism	"	90	3893
2	Dept Store	"	90	3894 B
2	Ben Bolt	Stan + Cach	87B	5013 B
3	Farriers Drill	Co + Pia	91	1020
3	Lam Lam	"	92	7572
3	Torie	"	77C	7790 C
3	Pumpkin Center	Stev	83B	3892 B
4	Bunco Steerer	"	82B	3900 B
4	School House	"	73C	3891 C
4	Geo Goo Eyes	Co + Pia	93	7693
4	Handicap Mch Song	Co + Pia	94	5706
6	Baptism	Stev	90B	3893 B
6	Hotel	"	86C	3886 B
6	Pumpkin Center	Stev	83C	3892 C
7	Lam Lam	Co + Pia	92B	7572 B
7	Handicap Mch Song	" "	94B	5706 B
7	Farriers Drill	" "	91B	1020 B
7	Farriers Drill	" "	91C	1020 C
7	Baptism	Stev	90C	3893 C
8	Hosanna	Stan + Cach	95	5018
8	Chinese Laundry	Stev	96	3902
8	Daily Paper	"	97	7298
8	Geo Goo Eyes	Co + Pia	93B	7693 B
9	Old Hundred	Stan + Cach	98	
9	Abide with me	" "	99	5019
9	Ninety + Nine	Kough	100	5016 B
9	Nazareth	"	101	5017

33 - 257

1901				
Mch 9	Handicap March	Co + Pia	94C	5706 C
9	Balmoral	" "	78B	7823 B
10	Handicap March	" "	94D	5706 D
10	Balmoral	" "	78C	7823 C
10	Geo Goo Eyes	" "	93C	7693 C
10	Abide with me	Stan	99B	5019 B
11	Lightning Rod	Stev	102	7333
13	Ananias Club	"	103	7846
13	Like a Girl	Denny	104	7159
13	" "	"	104B	7159 B
13	Naughty Banana	"	105	7154
13	Ain't you my Lulu	"	106	7593
13	Naughty Banana	"	105B	7154 B
13	Malinda Hinda	"	107	7774
14	Like a Girl	"	104C	7159 BC
14	Man Took a Girl	"	108	7197
14	Jim Lawson	Stev	109	7847
14	Ninety + Nine	Stan	100B	5016 B
14	Nazareth	"	101B	5017 B
14	Abide with Me	"	99B	5019 B
14	Hosanna	"	95B	5018 B
14	Hosanna	"	95C	5018 C
15	Chinese Laundry	Stev	96B	3902 B
15	Old Hundred	Stan	98B	B
15	Ben Bolt	Dal	110	7326
15	Ol Miserere	"	111	7325
15	Ol Miserere	"	111B	7325 B
15	Polish Nat Dance	"	112	7325
15	Raffi Cavatina	"	113	7633
15	Polish Nat Dance	"	112B	7325 B
16	Helen Hunt	Dal	114	7123
16	Raffi Cavatina	Dal	113B	7633 B
16	Helen Hunt	Dal	114B	7123 B

33-290

1901				
May 14	N.G. Imitation Bag Pipe	Dal	115	N.G. 7377
" 16	Scenes are Brightest	"	116	7453
" 16	Imitation Bag Pipe	"	1158	7377 B
" 16	Ben Bolt	"	1108	7326 B
" 16	Imitation Bag Pipe	"	1158	7377 C
" 17	Nazareth	Stan	1010	5017 C
" 17	Abide with me	Stan	990	5019 D
" 17	Arrival in N. York	Stw	618	3870 B
" 17	Scenes are Brightest	Dal	1160	7453 B
" 17	Imitation Bag Pipe	Dal	1158	7377 D
" 17	Scenes are Brightest	Dal	1160	7453 C
" 17	Ben Bolt	Dal	1100	7326 C
" 17	Helen Hunt	De	1140	7123 C
" 18	Old Hundred	Stan	990	C
" 18	Sarah from Syracuse	De	117	7692
" 18	Bicycle	Stw	888	3898 B
" 18	Nazareth	Stan	1010	5017 D
" 20	Automobile	N.G.	118	7814
" 20	Letter from Klondike	"	119	3833
" 20	Malaria	"	120	7653
" 20	Mining	N.G.	121	7784
" 20	Delmonico	"	122	7578
" 21	Automobile	"	188	7814 B
" 21	Washing the Gun	N.G.	123	7737
" 21	Chinese Laundry	Stw	960	3902 C
" 21	Waltz from Faust	Dal	124	7659
" 21	Then You'll Rem. Me	"	120	7458
" 21	Holy City	N.G.	126	7590
" 21	Carnival of Venice	N.G.	127	7824
" 21	Jim Lawson	Stw	1098	7847 B
" 22	Carnival of Venice	Dal	1278	7824 B
" 22	" "	"	1270	7824 C
" 22	Then You'll Rem. Me	"	1208	7458 B

32-322

1901				
May 22	All yr Faithful	Dal	128	7732
" 22	" " "		1288	7732 B
" 22	Malaria	Ken	1218	7655 B
" 22	Turkish Bath	Ken	129	7519
" 23	Man Took a Girl	De	1188	7199 B
" 23	Kissing	Ke.	1218	7784 B
" 23	Holy City	Dal	1268	7590 B
" 23	Holy City	"	1268	7590 C
" 23	Bicycle	Stw	880	3898 C
" 23	Then You'll Rem. Me	Dal	1208	7458 C
" 23	Yet letter from Klondike	Ke.	1190	3833 B
" 23	Arrival of Venice	Dal	1270	N.G. 7824 D
" 23	Ananias Club	Stw	1038	7846 B
" 24	And the Parrot said	De	130	7127
" 24	Kissing	Ke.	121	7784 C
" 24	Waltz from Faust	Dal	124	7659 B
" 24	Old Couldn't	De N.G.	131	7107
" 24	Old Couldn't	De.	131	7107 B
" 24	Old Couldn't	De.	131	7107 C
" 24	Old Couldn't	De.	131	7107 D
" 24	Styles of Singing	De	132	7205
" 24	Styles of Singing	De	132	7205 B
" 24	And the Parrot said	De.	130	7127 B
" 24	Holy City	Dal	126	7590 D
" 24	Daily Paper		978	7298 B
" 25	Malaria	Ke.	120	7653 C
" 25	I'm not Particular	N.G. De	133	7103
" 25	I'm not Particular	De.	133	7103 B
" 27	And the Parrot said	De.	130	7127 C
" 27	Waltz from Faust	Dal	124	7659 C
" 27	Delmonico	Sold & Engaged	220	N.G. 7578
" 27	Letter from Klondike	Ke.	1190	3833 C
" 27	Moon behind the Gun	Ke.	138	7737

30-352

1901.				
May 27	Come All Ye Faithful	Dil.	120	7732 C
27	Automobile	Kem.	120	7814 C
27	Kissing	Kem.	120	7784 B
27	Family Troubles	Dem.	134	6600
27	Family Troubles	Dem.	138	6600 B
27	Tack	Dem.	135	7843
27	Tack	Dem.	138	7843 B
27	Family Troubles	Dem.	134	6600 C
28	Whistling Rufus	Quinn	136	6953
28	Pat Malone	Stitted in nursing Quinn	137	7358 NG
28	Wait for Undertaker	Quinn	138	7669
28	Whistling Rufus	Quinn	138	6953 B
28	Shadows on the Door	Dem.	139	7105 NG
28	Go Tomorrow	Quinn	140	6923
28	Pat Malone	Quinn	137	7358 B NG
28	Go To Morrow	"	140	6923 B
28	Go To morrow	"	140	6923 C
28	Go Tomorrow	"	140	6923 D
28	Tommy Murphy	"	141	7794
29	Glorious Beer	"	142	7393
29	Glorious Beer	"	142	7393 B
29	Glorious Beers	"	142	7393 C
29	Tommy Murphy	"	141	7794 B
29	Tommy Murphy	"	141	7794 C
29	Reuben Come to Town	"	143	7708
29	Reuben Come to Town	"	143	7708 B
29	Reuben Come to Town	"	143	7708 C
29	Wait for Undertaker	"	138	7669 B
31	Little Bridge	Nutter	144	2203
31	Sunny Southern Home	Quier	145	2225
31	Annie Laurie	Blind	146	2201 NG
31	Auld Lang Syne	"	147	2202
31	Auld Lang Syne	"	147	2202 B

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1901				
May 31	He Whistled up a tune	Quinn	148	7394
31	He Whistled up a tune	"	148	7394 B
31	Sunny Southern Home	Quier	145	2225 B
31	The Bridge	Quier	146	2203 B
31	Sunny Southern Home	Quier	145	2225 C
31	He Whistled up a tune	Quinn	148	7394 C
31	He Whistled up a tune	Quinn	148	7394 D
31	A Pipe Dream	"	149	7795
" 31	A Pipe Dream	"	149	7795 B
June 1	Auld Lang Syne	Quier	147	2202 C
1	Dancing on a Barn Floor	"	150	2213
1	Dancing on a Barn Floor	"	150	2213 B
3	As You Pass Down White Pike		151	1562
3	" " " " "	"	151	B 1562 B
3	" " " " "	"	151	C 1562 C
3	" " " " "	"	151	D 1562 D
4	Child Christ Rose	Na.	152	5720
4	Child Christ Rose	Na.	152	B 5720 B
4	Fatal Rose of Red	Na.	153	7601
4	Dixie is another Lincoln	"	154	7452
4	Dixie is another Lincoln	"	154	B 7452 B
4	Harvest Days are over	Har.	155	7670
4	Harvest Days are over	"	155	B 7670 B
4	Finding my mama there	"	156	7220
4	Finding my mama there	"	156	B 7220 B
4	Harvest Days are over	"	155	C 7670 C
4	Her Name is Rose	Na.	157	7537
4	Her Name is Rose	"	157	B 7537 B
5	Finding my Mama There	Her	156	C 7220 C
5	Finding my Mama There	Her	156	D 7220 D
5	Her Name is Rose	Na.	157	C 7537 C
5	Her Mamie is Rose	Na.	157	D 7537 D
5	Christ Rose		152	C 5720 C

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1901

Aug 5	Harvest Days are over -	Hal	153D	7670 D
5	Fatal Rose of Red	Na	153B	7601 B
5	Fatal Rose of Red	"	153C	7601 C
5	Just another Lincoln -	Na	154C	7652 C
5	Spanish Record -	Special		
5	"	"		
5	German Record	"		
6	House of too much trouble -	Nov	158	7731
6	House of too much trouble	"	158B	7731 B
6	Mick what do thew the kick -	Co	159	7489
6	Mick what do thew the kick	"	159B	7489 B
6	Mr. Conductor NO.	Hal	160	7219
6	Mr. Conductor	"	160B	7219 B
6	Mr. Conductor	"	160C	7219 C
6	Mr. Conductor	"	160D	7219 D
6	Sons of the Sea	Nat	161	7555
6	Sons of the Sea	"	161B	7555 B
6	Sons of the Sea	"	161C	7555 C
7	Every Race has a flag -	Co	162	7580
7	Every Race has a flag -	Co	162B	7580 B
7	Mick what do thew the kick	"	159C	7489 C
7	Vaudeville No. 4	Co	163	7549
7	Wish they do it now	"	164	5412
7	Vaudeville No. 4	"	163B	7549 B
7	Vaudeville No. 4	"	163C	7549 C
7	I have Nothy Home for you	"	165	7278
7	Say you love me Sue	"	166	7403
7	Every Race has a flag -	"	162C	7580 C
7	Say you love me -	"	166B	7403 B
7	I have Nothy Home	"	165B	7278 B
7	Wish they do it now	"	164B	5412 B
8	I have Nothy Home	"	165C	7278 C
8	Vaudeville No. 4	"	163D	7549 D

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1901.

June 8	Wish they do it now -	Co	164C	5412 C
8	Mick what do thew the kick -	"	159D	7489 D
8	Wa Dee + a Man -	Nat	167	4917
8	Kathleen Mavourneen	Nov	168	7368
10	Every Race has a flag -	Co	162D	7580 D
10	Heart Bound Down -	Nov	169	4914
10	Soldier + a Man -	NO.	167B	4917 B
10	Kathleen Mavourneen	"	168B	7368 B
10	Soldier + a Man -	"	167C	4917 C
10	Alpine Specialty -	Nation	170	4031
10	Sauerkraut -	Nation	171	4023
10	Original Unterkrab	"	172	4035
10	"	"	172B	4035 B
10	" Not Tested.	"	172C	4035 C
10	"	"	172D	4035 D
10	Sauerkraut -	"	171B	4023 B
10	Alpine Specialty	"	170B	4031 B
11	Didn't know till after -	Do	173	7104
11	" " "	"	173B	7104 B
11	Kathleen	Nov	168B	7368 B
11	Vaudeville -	Do	174	7536
11	Vaudeville	"	174B	7536 B
11	Vaudeville	"	174C	7536 C
11	Do thee anything else	"	175	7673
11	"	"	175B	7673 B
11	You never told	"	176	7126
11	"	"	176B	7126 B
11	I wyder Does your mother Wa	"	177	4030
12	Bryan Dance -	Do	178	6702
12	Bryan Dance	"	178B	6702 B
12	Could I kiss that	Do	179	6904
12	Can't think of	Do	180	7112
12	NO.	Do	180B	7112 B

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June 9	You never told	Dr	180 7126 C
9	I don't think	"	180 7127 B
12	Vaudeville	Dr	174D 7356 D
12	Pat Malone	"	137 7358
12	Gypsy Dance	Dr	178D 6702 C
13	Couldn't help it	Qui	181 7526
13	Couldn't help it	"	179B 6904 B
13	Gypsy Dance		178D 6702 D
13	Div. Americana	Dr	182 6703
13	Scene from Faust	"	183 7574
13	" "		183B 7574 B
13	Pat Malone	Qui	137B 7358 B
13	Scene from Faust	Dr	183C 7574 C
13	His little wife	Qui	184 6913
13	Road to Mandalay	"	185 6936
13	Nothing too good	"	186 7359
13	Happened to be there	"	187 6917
14	Scene from Faust	Dr	183D 7574 D
14	Spring Song	"	188 7195
14	His little wife	Qui	184B 6913 B
14	Hey tickle a girl	"	189B 6948
14	" " "	"	189B 6948 B
14	Reuben, Come to town	"	190D 7708 D
14	Happened to be there	"	187B 6917 B
14	Road to Mandalay	"	185B 6935 B
14	Schubert's Serenade	Dr	190 7192
14	Cut Ahead	Ken	191 3838
15	Money Over (my ch. tunes)	Ken	192 7607
15	Money Over (good old tunes)	Dr	192B 7607 B
15	Tiger Lily (my ch. tunes)	Qui	193 7577
15	Tiger Lily (good old tunes)	Dr	193B 7577 B
16	Cut Hunting	Ken	194 3841
16	Cut Hunting	"	194B 3841 B

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June 17	Star Dewy	Ken	195 3831
17	Oh Love	Ken	196 3834
17	Trip to Chicago	Ken	197 3836
17	At Church	Ken	198 3833
17	Oh trouble	Ken	199 3840
17	Trip to Chicago	"	197B 3836 B
17	If you love your baby	Dr	200 7691
18	Oh Love	Ken	196B 3834 B
18	Teddy Roosevelt	"	201 7757
18	Teddy Roosevelt	"	201B 7757 B
18	On Twins	"	202 7426
18	On Twins	"	202B 7426 B
18	Savage Mosquito	"	203 7554
18	Savage Mosquito	"	203B 7554 B
18	Hypnotism	"	204 7866
18	Hypnotism	"	204B 7866 B
18	Wedding Trip	"	205 3832
18	If you love your baby	Dr	200B 7691 B
18	Gingy Je Gum Glum	"	206 5452
19	Slide Kelly	Dr	207 1574
19	Alabama Moon	"	208 1523
19	Darktown is Out Dr		209 6905
19	" " "		209B 6905 B
19	Why don't you Band Clay	"	210 7842
19	Goodmandown	"	211 7687
19	Band is playing Dixie	"	212 7744
19	Goodmandown	Qui	211B 7687 B
19	Coonin Pea Patch	"	213 6957
19	Savage Mosquito	Ken	203C 7554 C
19	Little Alabama boom	Dr	208B 1523 B
19	Back to Arkansas	Dr	214 1514
20	My Creole lure	Qui	215 6571
20	Can't tell why I love	"	216 7795

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20	Can't tell why etc.	Mell.	216B 7595 B
20	" " "	"	216C 7595 C
20	Song of the Sun	South	217 7242
20	" " "	"	217B 7242 B
20	Can't tell why etc.	Mell.	216D 7595 D
20	My Bride Sue	"	218 6571 B
20	Always	Mell	218 7302
20	Home Sweet Home	"	219 1575 NG
20	Vaudeville	Quinn	220 7544
20	"	"	220B 7544 B
20	Slide Kelly	Co.	207B 1547 B
20	Always	Mell	218B 7302 B
20	Home Sweet Home	"	218 1575 B NG
20	Home Sweet Home	"	219C 1575 C
20	Living Easy	Quin	221 6919
21	Dark town is out	"	209C 6905 C
21	Strike up the Band	"	222 7552
21	Always	Mell	218C 7302 C
21	New World	Native	223 7775
21	New World	"	223B 7775 B
21	For all Eternity	"	224 7296
21	Everlasting Light	"	225 7776
NG	N.G.	" Hice	225B 7776 B NG
21	Always	Mell	218D 7302 D
21	Vaudeville	Quin	220C 7544 C
22	Everlasting Light	Na	225C 7776 C
22	Endless Day	Na	226 8031
22	Bethlehem	"	227 7496
22	For all Eternity	"	224B 7296 B
24	Auto me off at Buffalo	Du	228 1084
24	" " " "	"	228B 1084 B
24	Stand for Julia	"	229 7738 NG
24	Sweet Alice	Quin	226B 8031 B

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June 24	Bethlehem	Na	227B 7496 B
24	Schen. to Troy	Du	230 1048
24	Ayuba Dam	"	231 7178
24	Bethlehem	Na	227C 7496 C
24	Ayuba Dam	Du	231B 7178 B
24	Schen. to Troy	"	230B 1048 B
25	Friend we had in J.	Fu	232 7014
25	Beulah Land	Fu	233 7004
25	Annie Laurie	Quin	146 2201
25	All hail the power	Fu	234 7001
25	" " " "	"	234B 7001 B
25	Calvary	"	235 7005
N.G. 25	Almost persuaded	"	236 7002
N.G. 25	Friend we have in J.	N.G.	232B 7014 B
25	Beulah Land	"	233B 7004 B
25	Beulah Land	"	233C 7004 C
N.G. 25	Almost persuaded	N.G.	236B 7002 B
25	Military Man	Qui	237 7756
27	Stutteling Coon	Qui	238 6947
27	Jerusalem Lily	"	239 7729
27	Lady of your own	"	240 6952
N.G. 27	Stutteling Coon	"	238B 6947 B NG
NG	Honolulu Lady	NG	241 6930
27	Lady of your own	"	240B 6952 B
27	Military Man	"	237B 7756 B
27	Jumping Jim Jump	"	242 7456
28	Wa-Wa Camp Meeting	NG	243 6903
N.G. 28	Best in the House	"	244 6944 NG
28	Wa-Wa Camp Meeting	NG	243B 6903 B
29	Best in the House	Qui	244B 6944 B
29	You don't hand it to	"	246 6934
July 5	Soldier & a Man	Nor	167D 4917 D
5	Dark Alice	Co.	247 7889

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July 8	Schubert's Serenade - Hoo	248	7327
8	Sabbath Day - Quer	249	2207
8	Cradle of the Deep "	250	2217
8	Every day will be dum "	251	2287
8	Clock Baby Boy "	252	2211
8	Jolly in our Alley	253	2208
8	" " " "	253B	2208 B
8	Soldier's a Man - Hoo	167B	4917 B
8	" " " " "	167P	4917 P
8	Schubert's Serenade "	248B	7327 B
8	Mooney & his Bike Bell	254	7754
8	La Reine de Saba - M. Lucien	255	
9	Every Day will be dum - Quer	251B	2287 B
9	Hot Corn Medley N.Y. "	256	2212
9	Jerusalem - Barthel	257	
9	Carmen "	258	
9	Hot Corn Medley N.Y. Quer Vargas	256B	2212 B
9	Soledad on a cavalina -	259	12178
9	Holy City - Vargas	260	12148
9	Jerusalem - Barthel	257B	
9	La Juive "	261	
9	Clock Baby Boy Quer	252B	2211 B
10	La Amor - Vargas	262	12145
10	Mooney & his bike Bell	254B	7754 B
10	" " " "	254C	7754 C
10	La Campana - Vargas	263	12149
NG 10	Cracked "	263B	12149 B
10	Carrion de Raul "	264	12180
10	" " " "	264B	12180 B
10	Carcon de Amor "	265	12150
10	Jocondi - Barthel	266	
10	Lita - Cultura Alda	267	
10	Carmen "	258B	

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July 11	Carrion de Raul - Vargas	264C	12180 C
11	Holy City "	260B	12148 B
11	Campana de Carrion "	263C	12149 C
11	Carrion de Amor "	265B	12150 B
11	La Amor "	262B	12145 B
11	Clock & Business Bell	268	7755
11	" " " "	268B	7755 B
11	Been a Dreaming "	269	7850
11	" " " "	269B	7850 B
11	" " " "	269C	7850 C
11	Never trouble trouble "	270	7816
11	I Got Mine "	271B	7889 B
12	Never trouble trouble "	270B	7816 B
12	Corn Corn Corn "	271	7750
12	I Looking at you Liza Der	272	7671
12	I Got like that "	273	7109
12	I Got Mine Bell	271C	7889 C
12	Barbier de Seville - Barthel	274	
12	Sujetais Roi "	275	
12	La Temple du Roi de Thule "	276	
12	La Reine de Saba - M. Lucien	255B	
12	Barbier de Seville - Barthel	274B	
12	Lyanne "	277	
12	Anacreon "	278	
12	Bride Lady Like Chicken - Der	279	7332
13	Jerusalem - Barthel	257C	
13	Sujetais Roi "	275B	
13	Chick Beat the Band - Der	280	7807
13	Looking at you Liza "	272B	7671 B
13	I Got like that "	273B	7109 B
13	Back to Dixie Quer	281	2222
13	Church Scene "	282	2224
13	Tambourine Dodd	283	2133

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1901				
July 16	Sleighride Party	Quar	2814	2218 B
16	Marine Back to Civilization		2818	2222 B
17	Church Scene	"	2828	2224 B
17	Camp Meeting	"	285	2226
17	3.33 in the Morn	Dec	286	7808
20	Steamboat Leaving wharf	Quar	2838	2233 B
20	Weaver Service	"	287	7581
20	Sleighride Party	"	2848	2218 B
20	Sun a Philosopher	Fa	288	7798
20	Act go out with Reilly	"	289	7508
22	McCanty at Lenny fritches	"	290	1066
22	[illegible]	"	291	2234
22	Campmeeting	Dec	2858	2226 B
22	McCanty at Lenny pictures	Fa	2906	1066 B
25	Act Go out with Reilly	"	2898	7508 B
25	Old Black Joe	Co	8B	7484 B
25	You are hard Luck to me	Co	292	7429
25	You talking ragtime	Co	293	7419
25	Oh how I hate the overalls	Fa	294	7697
25	The papa was true	"	295	6706
25	Sweetest story ever told	Mel	296	1575
25	Hearts + flowers	"	297	7789
25	Dis Kid Should Have Married	"	298	7629
25	Annie Laurie	"	299	1503
26	Darkies Dream	Brooks	300	2605
26	Darkies Patrol	"	301	2606
26	Cocoanuts Dance	"	302	2604
26	Darky Tickle	"	303	2608
26	Days Recollections	Co	3B	7665 B
26	Boat leaving Other half	Quar	2830	2233 C
26	Weaver Service	"	2878	7581 B
26	Sleighride Party	"	2840	2218 C
26	What do you think of Hooligan	Fa	304	6705

32 — 705

1901				
July 26	Nothing to do but Work	Fa	305	1876
26	Lay in Patrick	Var	306	12167
26	Siciliana Dodd	Var	307	12203
27	Bercarolasen b. d. d.	"	308	12189
27	Aria del Trovador	"	309	12182
27	Dango Otero	"	310	12179
27	Yo Quiero un Besito	"	311	12153
27	Melancholy Rose	Co	312	7862
27	Sua from Louisiana	Dc	313	7512
27	Jiskon tip of my tongue	Fa	314	7271
27	Canciones del Universo	Co	315	12159
27	I need the money	Fa	316	7962
Aug 1	Such Doings	Dc	317	7582
1	Turkey in the Turk	"	318	7[illegible]
1	Widow Bloo for son	"	319	6602
1	Schimpf	Dot	320	12125
1	Bicycle	"	321	12126
1	Dalzer Conversation	"	322	12141
1	Non dal Diablo	Var	323	12199
1	El Toreador	"	324	12209
July 30	Siciliana	Band - Cyr	3078	12203 B
3	Kitty Me	Wing, Fitz	325	2041
Aug 1	Amy Blace Schumann	Dc	326	7901
1	Dalzer Conversation	Dot	327B	12141 B
1	Ave Grunewald	"	327	12129
2	" "	"	327B	12129 B
2	Golden Rein Stall	"	328	12127
2	Schimpf	"	328D	12125 D
2	Golden Rein Stall	"	328B	12127 B
2	" " "	"	328C	12127 C
2	Schimpf	"	328C	12125 C
2	Church Scene	Quar	2826	2224 C
2	Sun a Philosopher	Fa	288B	7797 B

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1901				
6 2	Gold Should Have Charm	Chas.	298B 7629	B
6 2	Love Old Sweet Song	Dr.	329 7010	
3	Lucy Dift	Stir	330 8003	
3	Coney Island	"	64 3878	
3	Love Sorrow	Fi.	331 7011	
3	Gypsy Love Song	Hoo	332 7163	
3	Sentinel Adolf	"	333 7677	
3	Gold Should Have Charm	Har.	334 5718	
5	Let All Obey	Hoo	335 4919	
5	Gypsy Love Song	"	332B 7163	B
5	Left Because I'd You Hat		336 7684	
5	In Old Madrid	Fi.	337 7007	
5	Soldiers of the Queen	Leach	338 7187	
6	Coney Island	Stir	64B 3878	B
5	Sentinel Adolf	Hoo	333B 7677	B
5	Left Because I'd You Hat		336B 7684	B
5	Torreador Song	Fi.	339 7013	
5	Believe	Fi.	340 7654	
5	Aint Data Shame	De	341 7875	
6	Girl Data Shame	"	341B 7875	B
6	Hot Stuff Patrol	Ass.	342 2616	
6	Fire Gift	Stir	330B 8003	B
6	In Old Madrid	Brooks	343 2617	
"	" "	"	343B 2617	B
6	Sunshine is come again	Quer	271B 2234	B
6	Camp Meeting	Stir	89B 3896	B
6	Ave Bus	"	75B 3883	B
6	Vesper Service	Quer	287C 7581	C
6	Happy Days in Dixie	Brooks	344 2613	
6	Eli Captain March	"	345 2610	
6	Darkies Awakening	Ass.	346 2607	
"	" "	"	346B 2607	B
6	Niggerina Jet	"	347 2625	

33 — 770

6 7	Happy Days in Dixie	Brooks	344B 2613	B
7	Stars & Stripes	Brooks	348 2632	
7	King cotton March	"	349 2619	
7	Adrianna	"	350 2623	
7	Love Sorrow	Fi.	331B 7011	B
7	Love Old Sweet Song	"	329B 7010	B
7	Bed at Picture	Fa.	290C 1066	C
7	Charior Gold	N Yor.	354 4909	
7	Torreador Song	Fi.	339B 7013	B
7	" " "	"	339C 7013	C
7	Ultimo Adios	Car.	352 12162	
8	Crescent Dance	Brooks	342B 2604	B
8	Darky Tickle	N.Y.	303B 2608	B
8	Believe	Fi.	340B 7654	B
8	Darkies Dream	Brooks	300B 2605	B
8	Melancholy Moon	Co.	312B 7862	B
8	" "	"	312C 7862	C
8	Rom. del Dillo	Ber.	323B 12199	B
8	De tin Patrie	"	306B 12166	B
8	Siciliana	"	307C 12032	C
9	I need the Money	Fav.	310B 7908	B
9	What do You Hear Than	"	304B 6105	B
9	" " "	"	304C 6105	C
9	Yo Quiero un Beuto	Var.	311B 12155	B
9	Barcarola en Bolero	"	308B 12181	B
9	Dance Otero	"	310B 12179	B
9	Nothing to do But	Fav.	305B 1076	B
9	Aria Il Trovador	Var.	307B 12182	B
12	Longing for you	Na.	353 7871	
12	Threw the Corsallo	Fav.	294B 7697	B
12	Soldiers of the Queen	Fick.	338B 7187	B
12	Cradle of the Deep	Jnor.	250B 2217	B
12	Nothing to do But	Fav.	305C 1076	

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Aug. 1891

1/12	I should have married	Nat. D.	390c.	7629	B
1/12	Her Papa was there	Fav.	2986	106	B
1/12	Just on Top Tongue	"	3488	7870	B
1/21	Village Blacksmith	Hool	354	7280	
1/21	Down Yetthina cellar	N.G.	355	4918	
1/21	Longing for you	Nat.	3598	7871	B
1/12	A Warrior Bold.	Hool.	3598	4909	B
1/21	Little Black Me	Na.	356	7585	
1/3	Ganga	Var.	357	12158	
1/3	Because	Nat.	358	5710	
1/3	Ganga	Var.	3578	12158	B
1/3	Bird in a cage	Nat.	359	7587	
1/3	La Marcha Cidig	Var.	360	12174	
1/3	Cancion del Ciego	Var.	361	12161	
1/3	Little Black Me.	Nat.	3568	7585	B
1/3	La Marcha Cadig	Var.	3608	12174	B
1/3	Cuba Libri	Var.	362	12146	
1/4	Carry me back	Quar.	363	2237	
1/4	Kathleen Mavourneen	"	364	7532	
1/4	Singing in my Heart	Nat.	3596	7871	B
1/4	Bird in a Cage	Nat.	3598	7587	B
1/4	Bird in a Cage	Nat.	3596	7587	B
1/4	The Old Sexton	Hool.	365	4907	
1/4	Because	Nat.	3558	5710	B
1/4	Nina Pancha	Var.	366	12168	
1/4	Kentucky Home	Quar.	367	2223	
1/5	Monkey & the Turk.	Den.	3188	7867	B
1/5	Pleasant Jackson Son.	Den.	3798	6602	B
1/5	Hard Place.	Den.	3268	7901	B
1/5	Birch Doings	Den.	3788	7582	B
1/5	Old Heart	Old.	368	7542	B
1/5	Cauld Stop	Den.	369	7206	
1/5	Change do you good	Den.	370	7170	

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Aug 1891

1/5	Tick Tack Tocking	Den.	371	7688	
1/5	Big Black Annie	Den.	372	7801	
1/5	Cauld Stop	Den.	369B	7206	B
1/6	Kathleen Mavourneen	Quar.	364B	7532	B
1/6	Kentucky Home	Quar.	367B	2223	B
1/6	Old Virginny	Quar.	363B	2237	B
1/6	Big Black Annie	Den.	372B	7801	B
1/6	Tick Tack Tocking	Den.	371B	7688	B
1/6	Change do you Good	Den.	370B	7170	B
1/6	Cold Feet	Den.	368B	7542	B
1/9	He laid away	Var.	373	7892	
1/9	Mary Ann W.H.H. McGar.		374	7271	B
1/9	Valley of Shenandoah	Quar.	375	7798	
1/9	I got White man	Coll.	376	7779	
1/9	Mary Ann	Quar.	374B	7271	B
1/9	Valley of Shenandoah	Quar.	375B	7798	B
1/9	Vi G. Ou W.H.H.	"	375c.	7798	c
1/9	I got White man	Coll.	376B	7779	B
1/9	Old Kentucky Home	Quar.	367c.	2223	c
1/9	Carry me Back	Quar.	363c.	2237	c
1/9	Kathleen Mavourneen	" "	364c.	7532	c
1/9	Camp Meeting	Steve.	87c.	3892	c
1/20	Stock Exchange	Steve.	67c.	3887	c
1/20	Daily Paper	Steve.	97c.	7298	c
1/20	Bunco Steerers	Steve.	82c.	3900	c
1/20	Daily Paper	Steve.	97B	7298	B
1/21	Coney Island	Steve.	64B	3878	B
1/21	5th Ave. Bus	Steve.	75c.	3883	c
1/21	Colleville Coon	Coll.	377	7664	
1/21	Fire Dept	Steve.	330	8003	c
1/21	Lightning Rod	Steve.	102B	7333	B
1/22	Mindy Lee	Coll.	378	7404	
1/22	Bunco Steerers	Steve.	82B	3900	B

Aug/01

1/22	Lightning Rod,	Stew.	102c	7333
1/27	Madrid Vigo	Ver.	379	12163
1/27	Serenata Aragonesa	"	380	12188
1/27	"	"	380B	12188 B
1/27	Sicilianaen Bar-Rua	"	381	12186
1/27	Cnanica Gelub.	Stew	102c	7846C
1/27	Dermen Language Record	Special		X
1/27	Aguanta Hasta, etc	Ver	382	12206
1/27	Habanera	"	383	12175
1/27	Madrid Vigo	"	379B	12163 B.
1/27	La Mulata Gallejuo	"	384	12208
1/27	Madrid Vigo	"	379C	12163 C
1/27	E.C. Juramento	"	385	12156
1/27	La Mulata Gallejia	"	384B	12208 B
1/27	Aguanta Hasta	"	382B	12206 B.
1/27	Habanera Carmen	"	383B	12175 B.
1/27	E.C. Juramento	"	385B	12156 B.
1/27	La Fiesta del Guijuelo	"	386	12170
1/27	La " "	"	386B	12170B
1/28	Serenade Mozkowsky	Orch	387	7418
1/28	Stefani Garotte	Vocal	388	8029
1/28	Serenata de Guinot	Ver.	389	12200
1/28	" " "	"	389B	12200 B
1/28	Arionette	Ver.	390	7387
1/28	Sol Les Huguenots	"	391	7698
1/28	" " "	"	391B	7698 B
1/28	Dance un Bro Guarachi	Ver.	392	12183
1/28	" " "	"	392B	12183 B
1/28	Spanish Record		XX	
1/28	Spanish Record		XX-1	
1/28	" "		XX-2	
1/28	French Record		X-2	
2/1	Nor Sport Tribe		1030	6673

Aug/01

29	Pity to waste it - Doc		394	7134
29	Mandy Lemy Lady Love	"	395	7200
29	" " " "	"	395B	7200 B
29	Doing a little bit -	Vocal	396	7129
29	Serenade Mozkowski	"	397B	7418 B
29	Don't it tickle you Do		397	7186
29	" " " "	"	397B	7186 B
29	Johnny + his camera	"	398	7111
29	Serenade Mozkowski Orch		397C	7418 C
29	Arionette	Vocal	398B	7387 B
29	Stefani Gav.	"	388B	8029 B
29	Jonda fain Tyrol	"	399	7386
30	Nig. to waste it N.G.	Ver.	394B	7134 B
1	Arionette	Vocal	398C	7387 C
1	Medley Overture N.G.	Orch	400	699
1	N.G. " False	"	400B	699 B
1	Stefani Garotte	Vocal	388C	8029 C
1	Tal Sure be Lucky M.Do.		401	7130
1	Sol Key Back N.G. Dod		402	7923
1	" " N.G. "		402B	7923 B
1	Chelman Dodd	"	403	7101
1	Doing a little Bit	"	396B	7129 B
1	Chelman	"	403B	7101 B
31	Pity to waste it		394C	7134 C
1	Wagner Belt	Orch	404	633
1	N.G. " W.A.M.	"	404B	633 B
1	Hearts + Flowers	"	405	7442
1	Stefani Garotte	Vocal	388D	8029 D
1	N.G. Blues Stalk W.M.	Orch	406	629
	N.G. W.A.M.	"	406B	629 B
		"	406C	629 C
	The Amer Church	"	407	7442
	Tell Mr Sunset again	"	408	623

33-934

1901

Sept.

3	N.G. Musical Falsa Conceptions Cach	409	555 NG
	N.G. Falsa	409B	555-B NG
	My Bab from Boston	410	713
	Lunch Polka	411	692
	Valse Bleue	412	7760
	Sol from Fortune Teller	413	697
	La Gallina Cav.	414	12197
4	El Cafe P. Rico	415	12093
	La Paloma	416	12102
	" " "	416B	12102B
	Jota de Las Nieves Nabi	417	12189
	" " " "	417B	12189B
	Sitri Amaras	418	12160
	Tua Gracias	419	12190
	Jota de Las Nieves	419C	12189C
	Sitri Amaras	418B	12160B
	Jota Mide del Bodrio	420	12177
5	La Puerta de mi Bohio	421	12193
	Serenata Dona Juanita	422	12157
	Hym. Nat. Mexicana Wood	423	12169 NG
	Guarda Esta Flor	424	12204
	Ave Maria (Cav. Rus.)	425	12187
	La Bimaroncita	426	12196
	El Cafe de Puerto Rico	415B	12093B
	Paso	427	12185
	Deseos	428	12165
	Doctor Eisenbein Wah	429	4032
6	La Donna e Mobile Ver	430	12016
	El Balsa	431	12095
	" " "	431B	12095B
	Ave Maria (Cav. Rus.)	425B	12187B
	La Donna e Mobile	430B	12016B
	Di Provenza	432	12098

31-965

Sept.

7	Non e Ver Cav.	433	12094
	" " "	433B	12094B
	Mattinata	434	12017
9	Tangos de la Mengilda	435	12201
9	La Morena	436	12003
9	Deseos	428B	12165B
9	Ave Maria (Cav. Rus.)	425C	12187C
	Di Provenza	432B	12098B
	Dio Possente	437	12099
	Canzone del Pater	438	12101
	Di Provenza	432C	12098C
	El Cafe de P. Rico	415C	12093C
	Dormi Pure	439	12109
	Dio Possente	437B	12099B
	Canzone del Pater	438B	12101B
	Mattinata	434B	12017B
10	La Bimaroncita	426B	12196B
	La Puerta de mi Bohio	421B	12193B
	Tua Gracias	419B	12190B
15	La Mia Bandiera	440	12034
	Serenata de la Merida	441	12152
	" " " "	441B	12152B
	O Paradiso	442	12030
	La Morena	436B	12003B
	Jota de la Madre del Bando	420B	12177B
	Laughing Song - Stev	443	4004
	Laughing Coon	444	4005
	There ain't a word	445	3904
	Laughing Song	443B	4004B
11	Serpolice Cav.	446	12048
	Torador Song	447	12020
	Dime de Dariballi	448	12024
	Serenata de la Merida Bracht	441C	12152 NG

33—998

1901
September

11	La Serenade de Paloma	Var.	469 12147
	Ophelia	Var.	4668 12048 B
	Laughing Coon	Stev	4948 4005 B
	"		4940 4005 C
	Hello Central	Var.	450 7852
	Funiculi Funicula	"	457 12015
	La Mia Bandiera	"	440 12034
	" " "		4408 12034 B
	Funiculi Funicula	"	4578 12015 B
12	Whistling Coon	Dud	452 4012
	Mr. Laphotep the slip	"	453 1070 NG
	Whistling Girl	"	454 4013
	Father speak to Mary	"	455 1131
	Whistling Coon	"	4528 4012 B
	Mr. Laphotep the slip	"	4538 1070 B
	" " " "		4538 1070 C
	Whistling Girl	"	4548 4013 B
	Cheemie	"	456 7950
	El Relampago	Var	457 12157
	Mariannina	"	458 12033
	El Relampago	"	457B 12157 B
	Ahdela mora	"	459 12021
	" " " "		459B 12021 B
	Toreador Song	"	447B 12020 B
	" "		447C 12020 C
13	Mary was a Maid, Dud		460 7498
	Village Choir " "		461 7550
	Pouch of a Hard " "		462 7865
	I never home till morning " "		463 1087
	" " " " " "		463B 1087 B
	Vaudeville Specialty	Dud	464 7548
	Quieta a Quella	Var	465 12031
	Three Little Owls	Stev	466 3907

32—1030

1901
September

13	Mariannina	Var.	458B 12033
	Three Little Owls	Stev	466B 3907 B
	There ain't a Word	"	4652 3904
	Old Bull Dough	"	467 3903
	There Ain't a Word	"	465C 3904 C
	Whistling Coon	Dud	452C 4012 C
	Girl Wanted	"	468 1027
	Father speak to Mary	"	455B 1131 B
14	My Sunday Girl	"	469 7227
	Village Choir	"	461B 7550 B
16	Mary was a Maid	"	460B 7498 B
	Tale of a Kangaroo	"	470 7685
	Mary was a Maid	"	460C 7498 C
	Waiting for Julia	"	229B 7738 B
	Vaudeville Specialty	"	464B 7548 B
	Chin Chin Chinaman	"	471 1011
	My Sunday Girl	"	469B 7227 B
	Tale of a Kangaroo	"	470B 7685 B
	" " " "	"	470C 7685 C
	Waiting for Julia	"	229C 7738 C
	Chin Chin Chinaman	"	471B 1011 B
17	Roll on Silver Moon	Nat. Quick	472 7523
	Einstein Tale of a Tub	Stale	473 7780
	German Hunter's Song	Nat.	474 4029
	Vaudeville Specialty	Dud	464C 7548 C
	Waiting for Julia	"	229D 7738 D
N.G.	German Hunter's Song	Nat.	474B 4029 B
	Roll on Silver Moon	"	472B 7523 B
	Rock-a-bye Baby	"	475 4036
	Einstein on Ocean	Stale	476 7538
	Vaudeville Specialty	"	477 7843
	" " "	"	477B 7543 B
NG	Rock-a-bye Baby	Nat.	475B 4036 B

32 – 1062

1901
Sept

12	German Hunting Song	Nat	474 C	4027
"	Hush-a-bye Baby	"	478	4021
"	Roll on Silver Moon	"	472 C	7523
"	Sleep Baby Sleep	"	479	4027
18	" " "	In Demand	480	4028
"	Einstein talks about the Sh.		481	7702
"	" at Vaudeville	"	482	7937
"	Sleep Baby Sleep	War	479 B	4027 B
"	" " Silver	"	480 B	4028 B
"	Vaudeville Specialty	Sh.	477 C	7543 C
"	Einstein at Bize Fight	"	483	7573
"	" " "		483 B	7573 B
"	Hush a Bye Baby	Orch. War	478 B	4021 B
"	Einstein at Vaudeville	Sh.	482 B	7937 B
"	" on the Ocean	"	476 B	7538 B
"	" talks about the	"	481 B	7702 B
"	M. & Pi. Medley in Mus.		484	7482
20	Wait Mary Jane Lee	Cor. Ha	485	5410
"	Warmest Baby	" "	486	5465
"	Moon too Black	" "	487 A	5469
N. B.	Warmest Baby (Scratched by G. H. in running)	" "	486 B	5465 B
"	Old Bill Jones	" "	488	7437
"	Allow me to come to chuck	" "	489	5468
"	Moon too Black	" "	487 B	5469 B
"	" " "	" "	487 C	5469 C
"	When you ain't got no money	" "	490	5467
"	Old Bill Jones	" "	488 B	7437 B
"	Wait my Julie	" "	485 B	5410 B
"	Bowery Bantam Bull	" "	491	5228
"	Einstein about the Sh.		481 C	7702 C
"	Vals Tza Dolondrinas	Var	492	12159
"	Oye Gustan Todas	"	493	12082
"	Mandolenata		494	12081

33 – 1095

Sept.

21	Ave Maria (Bonno)	Var.	495	12210
"	Oye Gustan Todas	"	498 B	12082 B
"	El Gorio Triqo	"	497	12047
"	Mandolenata	"	494 B	12081 B
"	Queen te Llamo	"	496	12012
"	Vals Tza Dolondrinas	"	492 B	12159 B
23	Banks of Wabash	Mel.	498	1570
"	Queen te Llamo	Var.	496 B	12012 B
"	El Gorio Triqo	"	497 B	12047 B
"	El Gorio Triqo	"	497 C	12047 C
"	" "	"	497 D	12047 D
"	Mandolenata	"	494 C	12081 C
"	Ave Maria (Bonno)	"	495 B	12210 B
"	La Serenata	"	499	12081
"	" "		499 B	12081 B
"	Canto de Amor	"	500	12010
"	Old Green Oak Home	Mel.	501	7371
"	Absence makes heart	"	502	7870
"	Sing that Refrain	"	503	1574
N. B.	Banks of Wabash	N.O.	498 B	1570 B
"	Old Green Oak Home	"	501 B	7371 B
"	Sing that Refrain	"	503 B	1574 B
"	Story of the Rose	"	504	7258
"	" " "		504 B	7258 B
24	Angela Serenade	Orch	505	502
"	" " "		505 B	502 B
"	Meeting of Blue & Gray	"	506	583
"	Bonnie Briar Orch.	"	507	571
"	" "	"	507 B	571 B
"	Love Dreamland Waltz	"	508	574
"	" "	"	508 B	574 B
"	Sel. from Burgomaster	"	509	7785
"	" "	"	509 B	7785 B

1901
Sept.

24	Fortune Teller March Ow.	510	668
	Langes Flower Song "	511	7920
N.G.	Beautiful Obiah Mazurka	512	1530 N.G.
25	If I only could Stan.	513	7133
"	An Innocent Maid "	514	7630
"	If I only could "	513B	7133 B
"	An Innocent Maid "	514B	7630 B
"	Bonnie d'Avril Orch.	515	7891 N.G.
"	Angels' Serenade "	515C	502 C
"	Bonnie d'Avril "	515B	7891 B
	~~Bonnie Brier March~~ "	~~511~~	
"	Bel Rob Roy "	516	577
"	Langes Flower Song "	511B	7920 B
"	Bonnie Brier March "	511C	511 C
"	Langes Flower Song "	511C	7920 C
"	Bonnie d'Avril "	515C	7891 C
"	Bluet Gray Waltz Orpheus "	506B	583 B
M.G.	Langes Flower Song "	511D	7920 B N.G.
26	Ah non Credevi Tu Var.	517	12022
"	Consos "	518	12080
"	Lasgo al Factotum "	519	12025
N.G.	Lucia " " "	519B	12025 B N.G.
"	Di tu se fedele "	520	12072
"	Deserto Sulla Terra "	521	12019
"	King Musketeers, Stan.	522	7469
"	" " " "	522B	7469 B
"	Ah Non Credevi tu Var.	517B	12022 B
"	Hundred Fathoms, — Stan.	523	5928
"	King Musketeers, "	522C	7469 C
"	Consos, Var.	518B	12080 B
"	Di tu se fedele "	520B	12072 B
"	Vieni Mia "	524	12049
"	Ah Non Credevi tu "	517C	12022 C

1901
Sept.

27	Deserto Sulla Terra Var.	521B	12019 B
"	Vinista Mia Vandalia "	524B	12049 B
"	Innocent Maid Stan. & Ow.	514C	7630 C
N.G.	Sweet Sweet Bird "	525	502 N.G.
"	A la Luna Var.	526	12000
	~~An Innocent Maid Stan.~~		~~7630 C~~
"	La Tempestad Var.	527	12018
"	El Milagro de la "	528	12067
"	Ay Chiquita "	529	12009
"	Lola "	530	12014
N.G.	El Milagro de la " N.G.	528B	12067 B
"	La Sevillana "	531	12004
"	Ay Chiquita "	529B	12009 B
"	La Boca de Jefe "	532	12007
"	Perfume, Mezcla Soul Dance	533	Fox Trot
N.G.	Jardin de l'Alcazar "	534	N.G.
28	La Tempestad Var	527B	12013 B
"	El Milagro de la Virgen "	528C	12067 B
"	La Con Carline	535	
"	Bi Jetais Var. Dart	536	
"	" " " "	536B	
"	Mignonnette Jacrip	537	
"	L'Ombre		
"	Ophelia mi vorrei nel		
"	Giovane pensiero Dart	538B	
29	Ophelia mi vorrei nel		
"	Giovane pensiero Jacrip	539	
"	" " " "	539B	
"	Blue Danube Waltz Ow.	540	512
"	Am Commando "	541	676
"	Bride O Act "	542	619
"	Intermezzo Russe "	543	552
"	Pitti Serenade "	544	644
"	Blue Danube Waltz "	540B	512B
"	Sweet Sweetheart "	545	7767

1901
Sept.

30	Donau Weibchen - Ch	546	521
	Merry Minstrel "	547	584
	Homage to the Ladies "	548	547
Oct. 1	Ange d'Amour Waltz "	549	503
	Donau Weibchen "	546B	521B
	Luna Waltz "	550	790B
	Merry Minstrel Mch "	547B	584 B
	Ange d'amour Waltz "	549B	503 B
	Bucuna Jocelyn Dartes	551	
	Bouffa de Coddette		
	Sur Hyperion Lavoix	552	
	" "	552B	
	Si Je ne vous voyais pas		
	Mignon Dartes	553	
	Bucuna Jocelyn "	551B	
	Bouffa de Coddette		
	Madame Favart Marchal	554	
	Le Cor Galeno	555B	
	Chant de Charlemagne "	555	
	Air de Danse de Danse		
	L'Africaine Dartes	556	
	Le Chine et son pays		
	Le Voyage in Chine "	557	
	Dans le Sommeil		
	Si Jetais Roi Marchal	558	
	" " " "	558B	
	Le Chine et son pays Clement		
	Le Voyage in Chine Dartes	557B	
	Aalesp in the Deep Meyer	559	783B
	Bedouin Love Long "	560	783B
	" " " "	560B	783B
	Aalesp in the Deep "	559B	783B
	" " " "	559C	783B C
	Bedouin Love Long "	560C	783B C
	Tuttle Serenade Ch	544B	664 B
	Intermezzo from Chile "	545B	778 B
	Bride Elect "	542B	619 B
	In Summer Mch "	541B	676 B
	Luna Walzer "	550B	790 B
	Homage to the Ladies Waltz	548B	547 B

1901
Oct.

3	Forget Me Not Waltz Ach	561	536
	La Paloma "	562	565
	Anvil Chorus "	563	504
	La Senorita Waltz "	564	566
	Espanita Waltz "	565	532
	La Senorita Waltz "	564B	566 B
	La Paloma "	562B	565 B
	Dancing on Roulette for "	566	519
	Bathing on Beach N.Y.	567	584
	3 Vivers Cantate d'aoigny	568	
	La coostle e lo studente Canto lamessa - d'aoigny	569	
	Chio chio e lo Canto lamessa	570	1220
	Intermezzo Russel Ach	545B	552 B
	Forget Me Not Waltz "	561B	536 B
4	Santiago Waltz "	571	607
	Dancing on Roulette for "	566B	519 B
3	aidar Quest assieme -		
	Ve Rossi	572	
	Luna - Deuetto Cantate - d'Arigny	568B	
4	La Rose du premier Bartel	573	
	Santiago Waltz Ch	571B	607 B
	Suwanee River "	574	523
	Morningon the Creek "	561B	534 B
	Suwanee River "	574B	523 B
	Ch Shedaddle "	575	597
	Espanita Waltz "	565B	532 B
	Ch Shedaddle "	575B	597 B
	Dolce in a heinroof "	576	597
	" " " "	576B	597 B
	Anvil Chorus "	563B	504 B
	Birds & Brook "	577	786
	Ave Maria "	578	664
		578B	664 B

1901

Oct.	Allons punta gira		
	Romeo + Juliette — Meyerbeer	579	
	Le Rêve (Faure) — Bartel	580	
	Hymne à la nuit (Bounoet) — "	581	
	Ah ici dans creature		
	Le Cœur et la Main — Meyerbeer	582	
	Allons punta gira		
	Romeo + Juliette — "	579B	B
	Chansonnette Rêve d'Orlande (Holmes) — Bartel	583	
	Ah Viderme creature		
	Le Cœur et la Main — Meyerbeer	582B	B
	Le jour du pleurer Rubinstein — Bartel	573B	
	Les Enfants — "	584	
	Ancien songe heureux		
	Philemon et Baucis — Meyerbeer	585	
	Quand le danger m'entoure		
	Le Drag. de Villars — "	586	
	Sylvelio de la Reine Mat.		
	Romeo Juliette — "	587	
	Le Cœur (Faure) — Bartel	580B	
	Le Printemps d'avant (Chaminade) — "	588	
	"		
	Chanson du Rêve Orlande (Holmes) — "	588B	
	Hypnotic a l'ej nuit	583B	
	Ballade de l'oiseau rich	581B	
	Rom. + Juliette — Meyerbeer	587B	
	Chansonnette Bonjour		
	Le Drag. de Villars — "	589	
	Que le temps heureux		
	Chil. et Baucis — "	585B	
	La jeune de Phenia (Coquelin) — Bartel	590	
	Ernani — Giuseppe Verdi	591	
	Bartel's Air for T.G.E.	X	
	Rigoletto — Giuseppe Verdi		
	Il mio — "	592	
	Tantar		
	Dove sei fatale — G. Rossini	593	
	Ecoute Bruxi vieux — Trebelli	594	
	Le Roi de la Forêt (Coquelin) — Bartel	590B	N.G.
	Quando Commemor		
	Trovatore — Giuseppe Verdi	595	
	Aida		
	Celeste Aida — "	596	
	Romance de Estrelle		
	Tannhäuser — Meyerbeer	597	
	Medley College Songs — Quiet	598	7568
	Lead Kindly Light — "	599	7625
	Imitation Medley — "	600	2236

1901
October

	Dodd.		
	Cradle of the Deep — Owens	601	7840
	" " " "	601B	7840 B
	Swift Sugenne — Fisher	602	7406
	Tosbate — "	603	7734
	" "	603B	7734B
	Gee + Irish Daces — Steele	604	3863
	Cradle of the Deep — Owens	601C	7840 C
	Imitation Medley — Sweet	600B	2236B
	" "	600C	2236 C
	A. P. A. — Steele	605	3861
	All Be your sweetheart — Fr.	606	7735
	Just as sun went Down — "	607	7118
	Tipary Man — Sel.	608	3862
	All Be your sweetheart — Fr.	606B	7735B
	" " " "	606C	7735 B
	French Lesson # 6		F.L. 6
	" # 3		F.L. 3
	" # 2		F.L. 2
N.G.	Dodd # 1	N.G.	F.L. 1
	" # 8		F.L. 8
	" # 4		F.L. 4
	" # 10		F.L. 10
	" # 7		F.L. 7
	" # 9		F.L. 9
	" # 2B		F.L. 2B
	" # 1B		F.L. 1B
	" # 5		F.L. 5
	" # 3B		F.L. 3B
	" # 4B		F.L. 4B
	" # 6B		F.L. 6B
N.G.	G. Burnet # 7B	N.G.	F.L. 7B
	" # 5B		F.L. 5B
	" # 8B		F.L. 8B

33 - 1319

1901
Oct.

10	French Lesson #9B		F.L. 9B
	" " #10B		F.L. 10B
	El Jaque	Var	609 12092
	La Calesera	"	610 12083
	La Cigarreras	"	611 12184
	Lead Kindly Light	Duet	5998 7625 B
11	Soldiers Farewell	"	612 7710
	La Cigarreras	Var	611B 12184 B
	La Calesera	"	610B 12083 B
	El Beloso	"	613 12082
	Irish on Parade	Stl	614 7470
	Ger. + Irish Reels	"	614B 3863 B
	Brindis Lab. Inst.	Var	615 12211
	Celeste Aida	"	616 12023
	El Beloso	"	613B 12082 B
	Celeste Aida	"	616B 12023 B
	Tengo El Negrito	"	617 12001
	Can. de el Saltarello	"	618 12212
	El Jaque	"	609B 12092 B
	Can. de el Saltarello	"	618B 12212 B
	A La Luz de la Luna	"	619 12188
	Soldiers Farewell	Duet	612B 7710 B
12	Chimes of March - Band		620 7425
	Bridal Bells	"	621 7826
	Strike up the Band	"	622 7618
	Hurrah Boys	"	623 7927
	Chimes of March	"	620B 7425 B
	Los Rambleros	Var	624 12210
	Hasta La Mañana	"	625 12008
	Tengo El Negrito	"	617B 12001 B
	Una Cosa Negra	"	626 12079
	" " "	"	626B 12079 B
14	A La Luz de la Luna	"	619B 12188 B

33 - 1352

1901
Oct.

14	Brindis	Var	615B 12211 B
	La Bayamesa	"	627 12136
	Tresita Chica	"	628 12006
	" "	"	628B 12006 B
	Hasta La Mañana	"	625B 12008 B
	Tengo El Negrito	"	617C 12001 C
	Romance Shadow Dance	Bd	629 7898
	Strike up the Band	Bd	622B 7618 B
	" " "	"	622C 7618 C
	Pan. Amer. Exp. Mch.	"	630 7826
	" " "	"	630B 7826 B
	Sec. Conn. Mch.	"	631
	Hands across the Sea	"	632 7307
	Hurrah Boys	"	623B 7927 B
	Duffel Schanzen	"	633 7638
15	Sec. Conn. Mch.	"	631B
	El Capitan	"	634 24
	" "	"	634B 24 B
	Duffel Schanzen	"	633B 7638 B
	Dare Devil Mch.	"	635 7323
	Duffel Schanzen	"	633C 7638 C
	Invincible Eagle	"	636 7877
	" "	"	636B 7877 B
	La Cinquantaine	"	637 7918
	Hurrah Boys	"	623C 7927 C
	American Eagle Mch.	"	638 7885
	" "	"	638B 7885 B
	Willow Grove Mch.	"	639 7328
	" "	"	639B 7328 B
16	Dec. Camp Meeting	"	640 122
	"	"	640B 122 B
	American Eagle Mch.	"	638C 7885 C
	Willow Grove	"	639C 7328 C

33-1385

1901
Oct.

16	Romance & Shadow.	Bd.	637B 7918 B
	La Cinquantaine	"	637B 7918 B
	" " "	"	637C 7918 C
	Dare Devil Mch	"	638B 7323 B
	Lincisa	d'Avigny	641
	" "	"	641B
	Sciala tu	"	642
	Di bella e tutta cor	Cantel. d'Avig.	643
	" " " "	"	643B
	Traviata Brindisi	Sala	644
	" "	"	644B
	Aida Ritornate a chi vi vuole	Rossi	572 B
17	Quant e bella	d'Avig	645
	Quant e bella	"	645B
	Sciala tu	"	642B
	Chi lo sa	Cantel.	570B
	Auspicio e la Comme Bella siccome angelo	Sala	646
	" " "	"	646B
	La risata	Cantel	647
	" "	"	647B
	Pagliacci	Sala	648
	"	"	648B
	Pagliacci Vesti la giubba	Dambricher	649
	" " "	Dambricher	649B
	Ave Maria (Tosti)	Var	650 12073
	" " "	"	650B 12073 B
18	Cancion Mac. Chilena	"	651 12088
	Sal a tu Ventana	"	652 12087
	Son los dos perfiditos	"	653 12214
	" " " perfiditos	"	653B 12214B
	Si en Sevilla Alla en son reina Amiraile	Bartel	654
	Sal a tu Ventana	Var	652B 12087 B
	Can. Mac. Chilena	Var	651B 12088 B

33-1418

1901
Oct.

18	Caballero de Grecia	Var	655 12077
	La Marsellaise	"	656 12218
	" "	"	656B 12218B
	Grand air du Tuyo La Reine de Saba	Bartel	657
	El Gato Negro	Var	658 12217
19	Grand air du Tuyo. Faillence de Carmen. La Reine de Saba	Bartel	657B
	Pour grand dame gran Mourelle La Reine de Saba	"	658
	Chanson de Triana Bassoon (Sight)	Bartel	610
	El Gato Negro	Var	658B 12217B
	Spanish Lesson # 1	S.L. 1	
	" " # 2	S.L. 2	
	" " # 3	S.L. 3	
20	" " # 5	S.L. 5	
	" " # 7	S.L. 7	
	" " # 8	S.L. 8	
	" " # 9	S.L. 9	
	" " # 10	S.L. 10	
	" " # 3B	S.L. 3B	
	" " # 4	S.L. 4	
	German Lesson # 1	G.L. 1	
	" " # 2	G.L. 2	
	" " # 4	G.L. 4	
	" " # 5	G.L. 5	
	" " # 6	G.L. 6	
	" " # 7	G.L. 7	
	" " # 8	G.L. 8	
	" " # 9	G.L. 9	
	" " # 10	G.L. 10	
22	Sel. from Mikado	Orch	662 613
	Eloise Polka	Orch	663 671
	" "	"	663B 671B
	" "	"	663C 671C
	Sel. from Mikado	"	662B 613B

33 - 1451

1901			
Oct 22	March from Strollers Co.	664 7936	
"	Ma Rag Time Baby "	665 700	
"	Circus Girl Waltz "	666 632	
"	Spanish Record # 6	S.L. 6	
"	German Lesson # 7 B	G.L. 7 B	
"	" " # 10	G.L. 10 B	
"	" " # 9	G.L. 9 B.	
25	Spanish Lesson # 5	S.L. 5 B.	
"	" " # 1	S.L. 1 B.	
"	" " # 4	S.L. 4 B.	
"	" " # 2	S.L. 2 B.	
"	" " # 9	S.L. 9 B.	
"	" " # 10	S.L. 10 B.	
"	" " # 8	S.L. 8 B.	
"	" " # 7	S.L. 7 B.	
"	German Lesson # 8	G.L. 5	
"	Smoky Moles. Arch.	667 712	
"	" "	667B 712B	
"	Trolley Gallop "	668 661	
"	The Strollers. Mrh. "	669B 7996 B	
"	Circus Girl Waltz "	666B 632 B	
"	Sol. King Dodo "	669 7959	
"	Awakening of the Corn "	670 657	
"	The Marchioness "	671 7928	
"	Romance from L'Eclair "	672 604	
"	Romance from L'Eclair "	672B 604B	
"	The Marchioness "	671B 7928 B	
"	Rag Time Baby "	665B 700 B	
"	Sol. from King Dodo "	669B 7959 B	
"	Limited Express "	673 650	
"	" "	673B 650 B	
"	Trolley Gallop "	668B 661B	
"	Spanish Lesson # 6	S.L. 6 B	

32 - 1483

1901			
Oct 25	Spanish Lesson # 7 C	S.L. 7 C	
"	German Lesson # 2	G.L. 2 B	
"	" " # 8	G.L. 8 B	
"	" " # 6	G.L. 6 B	
"	" " # 1	G.L. 1 B	
"	Noel Paien Barthel	674	
"	Si les Filles Malles ont		
	rimes Versaille Barthel	654B	
"	O celeste Aida "		
	Aida "	267B	
25	German Lesson # 3	G.L. 3 B	
"	" " # 4	G.L. 4 B.	
"	" " # 5	G.L. 5 B	
"	La Dude Du pagan		
	(Bouillon) Barthel	675	
"	" " "		
"	O mio fanciullo la tortora "	455B	
"	Hamlet "	676	
"	" " "	676B	
"	Bonne nuit petit oiseau		
	Suzanne "	277B	
"	Le Vieux Lion Sur Rupel		
	Faust "	677	
"	Bonsoir, adieu mon avenir		
	Le Roi de la Chase "	678	
"	Grand Père Il est venu		
	Pour conduire Roi de Thule "	276B	
"	Mort de Du Guesclin		
	Du Guesclin "	261B	
"	Chanson du Printemps		
	Le Chalet "	679	
"	Au Bal Chaque Dame Salade		
	Quentin Durward "	680	
"	Couplets de Chaste		
	Les Matines Chantées "	681	
"	Ah Happy Love image		
	Ah Happy Love image "	682	
26	Les Rameaux		
	(Chant) Barthel	683	
28	Adieu (Mignon Courage)		
	(Mignon) "	684	
"	" " "	684B	
"	Plantation Medley Aus	685 7857	
"	Gile Boola Gil "	686 7983	
"	" " "	686B 7983 B	
"	" " "	686C 7983 C	
"	Old Oaken Bucket "	4 5216	
"	" "	4B 5216B	

1901
Oct.

30	Old Oaken Bucket - Over.	4C 2216C	
	Moonlight on the Lake "	687 2238	
	" " " " "	687B 2238B	
	Darling's Dream of Me "	688 7945	
	" " " " "	688B 7945B	
	" " " " "	688C 7945C	
	Mandy Lee "	689 7557	
	Plantation Medley "	689B 7557B	
	Farmyard Medley "	2B 2229B	
29	Moonlight on the Lake "	687C 2238C	
	Mandy Lee "	689B 7557B	
	Le Vrai Amour Faust Bartel	677	
	Lucrezia Borgia di pietosi ignude Mielino	690	
	" " " "	690B	
	Vagnement ma bien aimée Le Roi d'Ys Bartel	691	
	" " " "	691B	
	Prisonnier de mon avenir Thor de Lahore "	678B	
	Valse		
	Ora e per sempre addio Mielino	692	
	" " " "	692B	
	Arrest der Gral Lohengrin Bartel	693	
	" " " "	693B	
	Chanson du printemps La Walkyrie "	679B	
	Donna ... Thale Giovanni La scuola di Ballo	276 C	
	Boheme Mielino	694	
	Orientazione di minuetto		
	" " " "	694B	
	Stanza Bartel	695	
30	Ballade Bar. ballade		
	Quentin Durward "	695B	
	Omphale Mielino	696	
	Il mio sol pensero estremo		
	Chiesa "	696B	
	Ah etta meninas Rossi	697	
	"	697B	
	Fiume di Lammermoor Tombe degli avi Mielino	698	
	Assolution		
	Bella figlia dell'amore "	699 12454	
	Ballo		
	Ballo Pastorale	700	

1901
Oct.

30	Forza del Destino		
	Pronti destieri Mielino	701	
	" " " "	701B	
	Lucrezia Borgia		
	Di piacere ingrato	6F	
	Faust		
	Salve dimora "	702	
	" " "	702B	
	Manon		
	Ombrine di de Grieux "	703	
	Pagliacci		
	Prologo Rossi	704	
	Ballo in Maschera		
	O scherzo od è follia Mielino	705	
	" " " " "	705B	
29	Pagliacci		
	Prologo Rossi	704B	
	Donna		
	Me protegge me difende Mielino	700B	
	Columbian C. P. Mch. Band	706 16	
	Over to Gamp "	707 58	
	Military Ralph "	708 7329	
	Hapsburg March "	709 32	
	" " "	709B 32B	
	Tambour der Garde "	710 52	
	" " "	710B 52B	
	Belle of N. York "	711 10	
	" " "	711 10B	
	Sel. from Boccaccio "	712 67	
	Sel. from Faust "	713 71	
	Sel. Der Freischutz Vo	714 70	
	Double Eagle Mch. "	715 19	
Nov. 1	N.G. " Dodd. "	715B 19B	
	Sel. Daughter of the Reg. "	716 69	
	" " " "	716B 69B	
	Overture to Gaimpa "	717B 38B	
	Sel. from Faust "	718 71	
	Independentia Mch. Bel	717 75.96	
	Anvil Chorus Bel.	661 7335	
	Mocking Bird "	718 7169	
	White Star While "	719 [illegible]	

32 – 1580

1901
Nov. 1

V. Botolink	Belmont	720	7334
"	"	720B	7334B
Independentes	"	717B	7596B
N.G.	Rud Hoos in master	717C	7596C
Mocking Bird	"	718B	7169B
Ship from mill	"	719B	7682B
Over the Waves	"	721	7597
" " "	"	721B	7597B
Anvil Chorus	"	661B	7335B
Over the Waves	"	721C	7597C
Botolink	"	720C	7334C
Mocking Bird	"	718C	7169C
Mamie	Myers	722	7821
N.B. Everywhere away	Hall	723	1568
Sounds from Tropic	Ver.	398B	7386B
Bonnet Lamoch			
del Fando	Rossi	724	
Quio de Tammuno			
Sulla tomba che	Milano	725	
" " "		725B	
Aiglette			
Bella figlia dell'amore	"	699B	
Aiglette			
Le donne e mobile	Sala	726	
Aida			
Morir si pura e bella	Verdi	727	
a Sirena	d'Arigny	728	
Mefistofele			
Quando nel paese	Milano	696B	
Il fischio			
" " "	Cantal Oling	729	
" " "		729B	
Tenatore	Tom		
Il Crociato	Elkins	730	
" "		730B	
Donna Fifi	Dautta		
a Sera e mamma	Cantal-Oling	731	
	Cantal-Oling	732	
Mamie	Myers	722B	7821B
Gran de Pippo	Ver.	733	12207
Bug Tell			
Il piccolo legno a undi	Sala	734	
Aiglette			
Le donne mobile		726B	

33 – 1613

1901
Nov. 6

Tosca) mon contemplation			
magi d'amb	Lacroix	735	
" "	"	735B	
O dolce o mon			
Rich. Cour de Lion		736	
Gran Guttana			
Le ochiule into e mio	Bantes	737	
Amore e mon dinto			
	Cantal-Oling	738	
" " "	"	738B	
Aida: Morir si pura e			
Bella	Gambar.	727B	
Donna Fifi: Dautta			
	Cantal-Oling	731B	
a Sera e mamma			
	Cantal-Oling	732B	
a Sirena			
Gran Tell: Il pino d'Arigny		728B	
ochenai			
Fa gondola mia	Tell	734B	
" " "	Milano	739	
O dolce o mon	"	739B	
Rich. Cour de Lion	Lacroix	736B	
Carotina: Canat	Dorta	740	
Chi? chi? Sono			
Fanatica	Milano	741	
Toll simplement			
	Belmont Dorta	742	
Oh! mio marchesi			
Oh! tu che marchesi	Rossi	743	
" " "	"	743B	
Pescatori di perle			
mi fa di vedi amore	Milano	744	
Andrea Chenier			
Non dì all'amore spavento	"	745	
" " "	"	745B	
Emilia			
(Romanza)	"	746	
Gaetano			
Giovo la tromba	Rossi	747	
Emilia			
(Romanza)	Milano	746B	
Chopin: Ly a un mda			
Un ch'ha lasciato	Dorta	748	
Toll simplement			
	"	742B	
Ora Pro nobis			
Bella amore un angelo	Rossi	749	
Ora Pro nobis			
Quelle non dal pine	Milano	750	
Tosca			
Prologo	Milano	751	
Quio di Tammuno			
Le chiese di	"	595B	
Quio di Tammuno			
Pa pera a me sicuro	"	752	
Bug			
Aiglette: Vivetta		721B	

32 — 1645

1901
Nov.

Otello - Ouim mi tema - Chiolino	753		V
Traviata - Aver de quando le venni - Dossi	754		V
Manon Fra voi belle Chiolino	755		V
Traviata Per me era fatale Dossi	593B		V
Magh. Lear Con ardo - Lacroix	756		V
Chatter Box Ecco sch			
La Figlia del Reggimento "	756B		V
Aida Quale Dunque le sorte - Lakme	757		V
Lucia Fulgida aura mia Dossi	757B		V
Les Huguenots "	748B		V
Ernani Oh Sogni mio Dossi	591B		V
Aida Quale Dunque le sorte - Lakme	757B		V
Tannhauser Mch. Bard	758	29	V
Lohengrin Bridal Mch. "	759	14	V
" " "	759B	14B	V
Tannhauser Mch. "	758B	29B	V
N.G. " N.M. "	758C	29C	N.G. V
Speedway March "	760	7763	V
" " "	760B	7763B	V
" " "	760C	7763C	V
N Lohengrin Bridal Mch.	759C	14C	N.G. V
La Marseillaise "	761	40	V
Wach Am Rhein "	762	96	V
American Dy. Mch "	763	4	V
" " "	763B	4B	V
" " "	763C	4C	V
Star Spang. Banner "	764	92	V
" " "	764B	92B	V
Mendel. Wedding Mch. "	765	120	V
N.G. Gloria Mozart 12 Mass "	766	116	N.G. V
Morning Noon & Night "	767	154	V
Wach Am Rhein "	767B	96B	V
La Marseillaise "	761B	40B	V
12 Wach Am Rhein "	762B	96B	V
Morning Noon & Night "	767B	154B	V

33 — 1678

1901
Nov.

12 Hallelujah Chorus - Cof	768	30	V
Nine Knights - March "	769	12371	V
N Star Span. Banner "	764C	92C	V
Gloria Mozart 12 Mass "	766B	116B	V
America "	770	2	V
" " "	770B	2B	V
" " "	770C	2C	V
La Marseillaise "	761C	40C	V
Russian Hymn "	771	63	V
" " "	771B	63B	V
Mendel. Wed. March "	765B	120B	V
Hallelujah Chorus "	768B	30B	V
Russian Hymn "	771C	63C	V
Morning Noon & Night "	767C	154C	V
18 Mendel. Wed. March "	765C	120C	V
Sequidillas - Manchegas Dov.	772	12213	V
La Golondrina "	773	12011	V
" " "	773B	12011B	V
" " "	773C	12011C	V
Nera Tu no vas Llorar "	774	12218	V
Carmela "	775	12018	V
" " "	775B	12018B	V
Ojos Azules "	776	12224	V
" " "	776B	12224B	V
Ma Me Gusta "	777	12220	V
" " "	777B	12220B	V
Ole Jota Española "	778	12222	V
" " "	778B	12222B	V
14 Como yo te he Querido "	779	12225	V
" " "	779B	12225B	V
Tuey Tu lo fino Bolero Dr. Cabello	780		V
Cafe Gallardo Cabello - Barnes	781	12587	V
Dimin Salem Dr. Bidel - Barnes			

Nov.
1901

4	Gadi Sevillana Pensiero Sr. Cabello	783		V
	" " "	783B		V
	Viva mi niña Coupletes Sr. Cabello	784		V
	" " " "	784B		V
	La Gaya dell'ora Cabello-Barma	785		V
	" " " "	785B		V
	La Desconsolata Cab-Barma	786		V
	Duo Bertas " "	786B		V
	La dolores Sr. Cabello	787		V
	Otello Sestetto diantesa Sr. B. del Barma	788		V
	Manara (Gatizico) Sr. Cabello	789		V
5	Otello sestetto diantesa Sr. Barma	789B		V
	El sano pasato Cabello-Barma	790		V
	Duo de los pasquas "	790B		V
	Manara (Gatizico) Sr. Cabello	789B		V
	La Dolores "	787B		V
	Jota "	787B		V
	Tosca por lo pino Cabello	791B		V
	La Sala de Anicita Sr. Balcone	791		V
	El Matrimonio "	792		V
	Tango al agua Pato	793		V
	Corp. del Cabello "	794		V
	La Hijas de Sra Romanza "	794		V
	Sel. from Robin Hood. Bd.	795	85	V
	" " " "	795B	85B	V
	Off to Camp "	796	58	V
	" " "	796B	58B	V
6	Storm & Sunshine "	797	112	V
	Off to Camp "	796C	58C	V
	Storm & Sunshine "	797B	112B	V
	Pilgrims Pakaus "	798	60	V
8	" " "	798B	60B	V
	Sel. Robin Hood "	795C	85C	V
	Anna Knight & Mch "	769B	723T B	V
	" " "	769C	723T C	V

Nov.
1901

8	Sel. Merry War Sanf.	799	80	V
	" " " "	799A	80A	V
	" " " "	799C	80C	V
	Marina Filiz mendo Sr. Lafloy	800		V
	" " " "	800B		V
	El Alfiere bianco Cabello-Barma	801		V
	" " " "	801B		V
	Marina Alerce mia José Ofilla	802		V
	La Bizarre Sano Bohemia Sr. B. del Barma	803		V
	" " " "	803B		V
	El Baile de Luis Alonso Duo Cabello-Barma	804		V
	La Aventura Duo Astorg Orangilda Cab-Barma	805		V
	El Relampago Volvorta a Sor un dia Sr. Lafloy	806		V
9	El Matrimonio Tango Sr. Cabello	792A		V
	El Matrimonio	807		V
	Bolera del Sereno " "	807		V
	El hijo de Sra Bolero " "	794B		V
	El Salto del Pariego Sorento " "	808	12519	V
	" " " "	808B		V
	El Relampago Volvera a ser un dia Sr. La Hoz	806B		V
	La Bruja Jota Sr. Cabello	809	12530	V
	" " " "	809B		V
	La Bicicleta Sr. B. del Barma	810		V
	" " " "	810B		V
	El Angel Caido Duo Sr. Lucado Cab-Barma	811		V
	" " " "	811B		V
	El Baile de Luis Alonso Cabello-Barma	804B		V
	La Aventura Duo Astorg Orangilda Cab-Barma	805B		V
	Tiempo robiletto Aguil dilla Sr. Cabello	812	12537	V
	" " " "	812B		V
	Gaya Mei fin Gaya Bamberdella	813		V
	Falstaff Quando sero poggio Rossi	814		V
	Ernani Io vedremo o meglio	815		V
	Pagliacci Sul gran suggetto Leoncavallo	816		V

Nov. 1901		
26	Ernani	
	Oscomo Carlo Rossi	817
	" " "	817B
	Italiani	
	Sperai tanto il delirio Gambe	818
	" " " "	818B
	Forza	
	Accordita armonia "	819
	" " "	819B
	Otello	
	Ciò mi terna "	820
	Africana	
	O Paradiso Sala	821
	" " "	821B
	Traviata	
	Ah di felice etera "	822 12493
	Der Freischutz Berg	714 70
26	Traviata	
	Ah di felice etera Sala	822B
26	Gloria Mozart (Thomas) Ed.	786C 116 C
26	Faga	
	Chi fin Faga Gambe	813B
	Otello	
	Ciò mi terna "	820B
	Falstaff	
	Quando erapaggio Rossi	814B
	Quand le Fondille (Simon)	
	La folie Lillo Roberto Carlen	823
	" " " "	823B
	Pagliacci	
	Un grande spettacolo Bem	816B
	E più un poco fem	
	Ah mon pauvre Le Lorrain	824
	" " " "	
	A Montagna Santalamen	825
	" " " "	825B
	Ah de la marquise	
	Samson et Dalila Lerroy	826
	Sogno de Paradis	
	Mireille (Gounod) "	827
	Faust (Gounod)	
	Invocation de Faust Carlen	828
	" " "	828B
	Aida	
	Celeste Aida Gambe	829 12512
	Sommeil de fleur	
	Manel (A. Thomas) Lerroy	830
	" " " "	830B
	Carmen	
22	Aggiungione in Tuvido Bertel	831
	" " " "	831B
	Quando dens Entrapelli amore	
	Mandolines (C. Adrien) Lerroy	832
	" " " "	832B

Nov. 1901		
22	Rachel quand du Seigneur	
	La Juive (Halevy) Lerroy	833
	Faisime	
	Ceur Dulciana (Mascagni) Bertel	834
	" " " "	834B
	O Dolcissime con fervore amant	
	Pelleas (Lemarcello) Bertel	835
	Dis moi que je ne rêve	
	Lucie de Lammermoor Lerroy	836
	" " " "	836B
	Enfin un jour tous deux se terr	
	Les mousquetaires de la reine Lerroy	824B
	Mamma Nellora	
	Freischutz (Weber) Lerroy	837
	Quand l'oiseau chante Bertel	838
	Lohengrin	
	Dans le Brabant Merchel	839
	Rachel quand du Seigneur	
	La Juive Lerroy	833B
26	Serenade a Minon - Bertel	840
	" " " "	840B
	Carmella (Loria) "	841
	" " " "	841B
	Comme a vingt ans	
	(Massenet) "	842
26	Stanu a Manon "	843
	" " " "	843B
	Comme a vingt ans	
	(Massenet) "	842B
	Quand Lorenzo dana	
	Pagliacci "	838B
	Lincinise (Rufus) "	844
	" " " "	844B
	Loisiau ~~[illegible]~~ de noces	
	Saul + Dagmi Merchel	839B
	" " " "	839C
	Air du 2e acte (Invocation de	
	Gounod - Faust) Merchel	845
	Mot de Valentine	
	(Faust - Gounod) "	846
	" " " "	846B
	Berceuse - Ah non ceur	
	Mignon Merchel	847
	" " " "	847B
	Fleur de los Campos - Var.	848 12230
	La Gamacuca "	849 12229
	" " " "	849B 12229B
	Si Tu m'aimais	
	(Massenet) Bertel	850

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33 — 1843

Nov. 1901			
26	La Palma	Var.	857 12227
	" "	"	857B 12227B
	Coplas de Boccacia	"	852 12231
	Donni Sure	"	858B 12104B
	Seguidillas Manchegas	"	772B 12213 B
	Jota de la Ganguela	Var.	853 12226
	Coplas de el Tonelero	Var.	854 12228
	Flor de los Campos	"	848B 12230B
	Chanos de Bribedi	"	448B 12024 B
	Sarrion del Arrimpe en Boccacio	"	855 12221
	" " "	"	855B 12221B
	Himno de Riego	"	856 12223
	Bolero de Matadora	"	857 12005
	" " "	"	857B 12005 B
	La Sevillana	"	831B 12006
27	Himno de Riego	"	856B 12223B
	Coplas de Boccacio	"	852B 12231B
	Jota de la Ganguela	"	853B 12226B
	Coplas de el Tonelero	"	854B 12228B
	Benediction of Prignasca	"	858 11
	Handicap March	"	859 31
	" "	"	859B 31B
	2nd Company Mch.	"	860 7783
	Little Kinkies	"	861 155
	Selection from Lucia	"	862 88
	" " "	"	862B 88B
	Handicap Mch.	"	839C 31C
	Hot Time March	"	863 103
	Little Kinkies	"	861B 155B
	Do way Back and	"	864 7988
	Sel. from Martha	"	865 79
29	Do Way Back and	"	864B 7988B
	2nd Company Mch.	"	860B 7783 B

32 — 1875

Nov. 1901			
26	German Lesson # 3		G.L. 3 m.
	" " #2		G.L. 2 m.
	" " #3		G.L. 3B.m.
	" " #4		G.L. 4 m.
	" " #4		G.L. 4B.m.
	" " #7		G.L. 7 m.
	" " #7B		G.L. 7B.m.
	Spanish Lesson #1		S.L. 1 m.
	" " #2		S.L. 2 m.
	" " #2		S.L. 2B.m.
	" " #1		S.L. 1B.m.
N.G.	Pinafore in music		S.L. 3 m. N.G.
	French Lesson #8		F.L. 8 m.
30	" " #8		F.L. 8B.m.
	Spanish Lesson #3		S.L. 3B.m.
	1st Time March		863B 103B
Oct. 2	French Lesson #8		F.L. 8 C.m.
	" " #8		F.L. 8B.m.
	German Lesson #3		G.L. 3 C.m.
	" " #3		G.L. 3B.m.
	" " #7		G.L. 7C.N.
	" " #2		G.L. 2B.N.
	Spanish Lesson #1		S.L. 1C.N.
	" " #3		S.L. 3C.N.
	Benediction of Prignasca	Var.	858B 11B
	2 Company Mch.	Bd.	860C 7783C
	1st Time March	"	863C 103C
	Selection of Prignasca	N.O.	858C 11C
	Cuadro de dulzaina	Sa. Bibl. Barmen	866
	20 Cano pasado por agua		
	La Viejecita	Cabello & Barmen	867
	Canciones de Spiro	Barmen	868
	" "	"	868B
	20 Cano pasado por agua	Cabello & Barmen	867B

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1901 Dec.	
2 El Barquillero Barcarole Cabello	869
" Don Cattivo Atto Gran Gotto tuo Cab.	870
" "	870B
" El duo de la africana Don and Elisa - Carmen	871
" El Cabello - Cavalleria Don Cavallaccio + Bar.	872 873C
" El Padrino - Ballo El Amore Don Arigo Dara	872B 12573
" Don Quichotte Atto Don Quichotte + Bar.	873
" " "	873B
" Don Arrigo Cab. + Bar.	874
" " "	874B
" Marina Gran Romanza - Oberto	875
" Gran Aria de Anthony duo del Balcon - Cab. + Bar.	876
" " " " "	876B
" Marina Gran Romanza - Oberto	875B
" La fiesta de S. Antonio Cab. + Bar.	877
" " "	877B
" Manon (Massenet) Sempre la stessa - Oberto	878
" Addio, addio, o Lorenzo - Rossi	879
" Gran Aria - Pur Oberto - Oberto - Cab. - Bar.	880 12585
" " "	880B
" Lucrezia Borgia Lucrezia - Donizetti	886B
" El duo de la africana Carmen	882
" Don Anbalcazar - Carmen	882B
" Lo adorando del Amore Carmen	881B
" Don Basilio - Indimi - Rossi	881
" " " "	881B
" Manon (Massenet) Il sogno - Mielino	882
" " "	882B
" Un Sempre - Pur Oberto Cabello + Bar.	883
" " "	883B
" Pagliacci Qualche Quella - Mielino	884
" Lucia di Lammermoor Fra poco morrò - Mielino	884B
" Spanish Lesson #10	S.L. 10 m.
" " 6	S.L. 6 m.
" " 10	S.L. 10 B.

33 - 1941

Spanish Lesson #9	S.L. 9 m.
" " #8	S.L. 8 m.
N.G. Dodd. #5	S.L. 5 m.
" " #7	S.L. 7 m.
French Lesson #7	F.L. 7 m.
" " #3	F.L. 3 m.
" " #7	F.L. 7 B. m.
N.G. Dodd. Spanish Lesson #9	S.L. 9 B. m.
" " #6	S.L. 6 B. m.
" " #7	S.L. 7 B. m.
French Lesson #3	F.L. 3 B. m.
Spanish Lesson #8	S.L. 8 B. m.
Coro di Lucia Rossi	885
Ballo - Lo mio tesoro - Aegiolino Lucia di Lammermoor Mielino	886
Faust Prologue	75B
Quando di Rigoletto Lucia al fontanini Rossi	885B
Aida - Ah, rivedrai la speranza Rossi	874B
Musica proibita Mielino	887
Rigoletto Canzone - Pur lo vedi il mio cuore Rossi	892B
Rigoletto Cortigiani del finchio - Rossi	888
Rigoletto Canzone del finchio "	888B
Don Pasquale Minuetto Mielino	889
Il Sole Luna Var.	526C 12000B
" "	526C 12000B
Il Paradiso "	464C 12030B
Lucrezia Quella "	465B 12031B
Canto d'Amor "	500B 12011B
La Boca di Rosita "	532B 12027B
Lucrezia Quella "	465C 12031B
Lola "	530B 12014B
Ballo in Maschera Lo chiesero al cielo Mielino	705C
Lola Var.	530C 12014B
Il Paradiso "	464C 12030B

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9	Gaya Scen. rico Mielino	890	
	Amorator		
	di quelle pare "	891	
	Barbiere - Romanza "		
	del Lirio	892	
	Embrazy - Sento una		
	pena indecente "	893	
	Duetto Tu che fai		
	l'addormentato - Bucolini	894	
	Quadro di Luciano Mielino	895	
	" " "		
	mamma - Marianti	896	
	Orfeo - Che vuol		
	dire Rachele allo "	703B	
	specchio		
	Duetto - Si tremenda	896	
	Vendetta Rossi	897	
	Belcanto Meschino		
	Ecstasy ed Follia Bucolini	705D	
	Mefistofele - Dai campi		
	dai fiori Mielino	898	
	Barbiere - Romanza "		
	del Fiore	898B	
	Incatore		
	di quelle pire Mielino	898B	
10	Traviata - Parigi o		
	cara Sala	899	
	Traviata - Pura siccome		
	un angelo Rossi	900	
	Rigoletto - Tu mi		
	bollente spirito Mielino	901	
	Faust - Salve fai l		
	addormentato Bucolini	894B	
	Romanza - Ah mio		
	Lenel ti dono Sala	902	
	Gaya del Destino		
	Ecco che mi sento agli Mielino	903	
	disprezzi "		
	Mefistofele - Dai campi		
	Quadro di Luciano "	898B	
	" " " " Mielino	904	
	Ah Dove è Stella - Angelo	904B	
	Traviata - Parigi o Sala	905	
	Traviata - Sola	890B	
	Ola - Duetto - Cantar Ang	906	
	Ad. Exposition Mel. Bel.	706B	16.0
	Sel. Dona Juanita Ger.	422	12157B
	Ultimo Addio "	352D	12162B
	Ogni Del Quisuno	353B	12154B
	Bocanda		
	Valzer Augo Sala	907	
	Duetto - Si tremenda		
	Duetto Rossi	887B	
	Il clarinetto		
	Duetto Cantar Ang	908	

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	Il clarinetto - Duetto		
	Cantar Ang	908B	
	Vorate ne rotte e lei		
	Duetto - Cantar Ang	906B	
	Ernani - Io vedremo		
	Gaspar andar Rossi	875B	
	Bocca e risposta		
	Duetto - Cantar Ang	910	
	Ernani - La quel dichi		
	Io lo vendetta Rossi	911	
	Ernani - O sommo		
	Giusto "	870	
	Lucrezia Alma		
	Virgina Sala	913	
	Forza del Destino Mielino	903B	
	Ecco che mi sento agli		
12	Ernani - La quel dichi		
	Io vendetta Rossi	911B	
	Don Pasquale		
	Serenata Sala	909	
	Bisonde		
	Cielo e mar "	907B	
	Traviata - Dei miei		
	bollenti spiriti Mielino	901B	
	Aida		
	Celeste Aida Gambadilla	899B	
	Romanza - Ah		
	Lenel ti dono Sala	902B	
	Gaya - Mai fui		
	Gaya Gambadilla	899B	
	Valzer		
	Le stelle "	914	
	La Figlia del Geldero		
	Cavatina Carmen	915	
	" "	915B	
	Chateau Margaux "	916	
	" "	916B	
	La Gran Via		
	Tango Mingilda "	917	
	La Bricolpidar "	918	
	Carmen		
	(Alvarez) Cabello	919	
	El Canto del		
	Precipicio (Alvarez) "	920	
13	Cantara (Alvarez) "	919B	
	El Canto del Precipicio "	920B	
	Como esta la sociedad		
	Coqueta del Valiente "	921	
	Cornegan Denza "	922	
	Como madre "	923	
	La multa de vivero		
	Cab. y Carmo	924	
	" " "	924B	
	Como esta la sociedad		
	Coqueta del Valiente Cabello	921B	
	Albaran de Lucia "	925	

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Dec.

12	La Marina (Completa)	Caballo	912		V
V	" " " "	"	912B		V
V	A Mi madre	"	913B		V
V	Yo soy Oro				
V	Tango Mingilla	Carmen	917B		V
V	Tarantela (Pura inocencia)				
V	un angelo	Rosa	900B		V
V	Ya Del Alma				
V	Joya de Coaretas	Caballo	926	12554	V
14	La Petita (Alvarez)	"	927		V
V	"	"	927B		V
V	El Diablo en el Poder	"	928		V
V	Romanza	"			
V	" " "	"	928B		V
V	Yo Soy Oro				
V	Sebastian Elisco	Carmen	929		V
V	La Borracha				
V	Canion del plomero	Caballo	930	12533	V
V	Antata Pity la				
V	Habanera - Bolero	"	931	12555	V
V	Tarantinesa - Copla				
V	Tonsy gordo	"	932		V
Band	El Bohemio				
V	Bellido	"	933		V
V	Alma Gitana				
V	Seguidilla	"	934		V
V	Alhambrago				
V	Romanza	"	935		V
V	" " "	"	935B		V
V	El Dictor (Alvarez)	"	936	12534	V
V	El Angel Caido				
V	Canion Aguadora	Carmen	937		V
V	" " "	"	937B		V
16	El Cabo (Alvarez)	Caballo	936B		V
V	El Bohemio (Ballade)	"	938		V
V	Yo Soy Oro				
V	Sebastian Elisco	Carmen	938B		V
V	Alma Gitana				
V	Seguidilla	Caballo	939B		V
V	Jos Borracho				
V	Canion del plomero	"	940B		V
V	Entre mi madre y				
V	el negro - Romanza	"	938		V
V	" " "	"	938B		V
V	Sevillana (Alvarez)	"	939		V
V	El Cabo Baguita				
V	Tango	"	940		V
V	" " "	"	940B		V
V	Jenda Waltz	Band	941	99	V
V	Overture to Diamond		942	56	V

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Dec.

14	Washington Post	Band	943	97	V
V	" " "	"	943B	97B	V
V	Calantha Waltzes	"	944	7863	V
V	" "	"	944B	7863B	V
14	Overture to Wm. Tell	"	945	57	V
V	Tropic to Tropic Mch.	"	946	7662	V
V	Washington Post Mch.	"	943C	97C	V
V	Jenda Waltz	"	941B	99B	V
V	Tropic to Tropic Mch.	"	946B	7662B	V
V	Spanish Fandango	"	947	91	V
V	Overture to Wm. Tell	"	945B	57B	V
V	Jenda Waltz	"	941C	99C	V
V	Overture to Wm. Tell	"	945C	57C	V
V	Spanish Fandango	"	947B	91B	V
V	Stephanie Gavotte	"	948	89	V
V	" " "	"	948B	89B	V
V	" " "	"	948C	89C	V
V	Calantha Waltzes	"	944C	7863C	V
18	Ave Maria (Sound)	Caballo	949		V
V	Certamen Nacional	Carmen	950		V
V	" "	"	950B		V
V	La Salsa de Amistad (Completa)	Caballo	951		V
V	" " "	"	951B		V
V	Las Alentas de Cordeiran	Caballo Carmen & Del Alcazar	952		V
V	" " "	"	952B		V
V	Ave Maria (Sound)	Caballo	949B		V
V	Las Pompitas (Completa)				
V	Esplanade Orator	Caballo	953		V
V	" " "	"	953B		V
V	El pañuelo roso	Caballo	954		V
V	El Zorro pizio	Carmen	955		V
V	Tango Los ojos negros	Hoz	956		V
V	Las Mujeres	Caballo + Carmen	957		V
V	" " "	"	957B		V

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18	Spanish Fandango	947C	9/C
19	El Guramento Romanza Caballero	958	
	Mariana Rosa vivida Opiles	957	
	" " "	958B	
	Marina Brindis "	960	
	" " "	960B	
	La Gran Via Caballero de Gracia Caballero	961	12548
	El Juramento Romanza "	958B	
	La Ciudad Salome Coplas Hilarion	962	
	" " "	962B	
NY	Spanish Lesson #4	S.L. 4 n.	NY
	" " #4	S.L. 4 Bn.	
	Spanish Lesson #5	S.L. 5 Bn.	
20	Sul Dentar de Cadiz Bardenas Bon Aralempo Caballero	963	
	" " " "	963B	
	La Mari Gaina Coplas Rio Arriba "	964	
	" " "	964B	
	La Gran Via Caballero de Gracia "	961B	
	El Bueno Pigro Tango Carmen	955B	
	El Pandero rojo Caballero	954B	
	Yo soy negrita "	956B	
	Dores a fui Emile Delay	965	12606
	Tamtöden Lottalak mby Emile Delay	966	12607
	" " "	966B	
	Hej Slovane Fr. Burkhakh	967	12610
	" " "	967B	
	Ach mon Ijak mimadrak Emile Delay	968	12608
	" " "	968B	12608
	Fantasie Sommanbula Bun	969	7626
21	" " "	969B	7626B
	Wedding of Duke v. Chaij Arch	970	7969
	Fantasie Sommanbula Bun	969C	7626
	Gavotte Gigue Arch	971	7935

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Dec.

23	Sallymount Ally Tuson	972	3609
	L'Etudiantina Waltz "	973	3608
	Sallymount Ally "	972B	3609B
	Home Sweet Home "	974	3606
	Polonaise Brilliant "	975	7253
	" " "	975B	7253B
	Gavotte from Mignon "	976	7173
	Polonaise Brilliant "	975B	7253C
	Gavotte from Mignon "	976B	7173B
	Love me Lize Bo. & Ch.	971B	7935B
	Tango de la Mingilda Vac	4358	12201
	Caballero de Gracia "	655B	12077
	Bamion del Quirnor "	315C	12152
	Cuba Libre "	342B	12166
	Yankee Doodle Stan	977	5007
	" " "	977B	5007
	Marcwork from Underteker		7669
24	Bridge Mary Myers	978	8010
	A Soldiers Bride "	979	7992
	Bridge "	978B	8010B
	Answer "	980	5800
	A Soldiers Bride "	979B	7992B
	" "	979C	7992C
	Bridge "	978C	8010C
	Answer "	980B	5800B
	Pabo Vac.		12185
	Scandekin Hochtrauer (Schmidt) Cortes	981	
	Scandekin Hochtrauer "	981B	
	Sicilian Hofman Lagr. Kitchiane (Massenet)	982	
	Ich liebt ein mädchen einmal Eilling (Adelige) Hofmann	983	
	Je pommerai toujours Ingrouvaise domanza (Cl. Cinka)	984	12620 Bolcanti
	Ich liebt ein mädchen Hochtrauer (Kuger) Schulmann	985	
	Je regrette du mieux le plus heureux Schulmann Jonas Hofmann	986	

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26	Einsiedlerlied v. mit Begleit.	987	Sutter
	Lyzeum Sammelmann (Lortzing)		
	Wenn ich ein Vöglein wäre (Beethoven) Nur Sutter	988	
	Mühlenglück (Bruno)	989	
	Ich wie so traurig Hofmann (Rigoletto (Verdi)	990	
	Ich bin Unschuld (Wagner) (Tannhäuser) Hofmann	991	
	Ach wie so traurig (Rigoletto) (Verdi)	991B	
	Aus der Jugendzeit (Reissiger)	992	
	Aus Dinorah (Meyerbeer) F. Schumann	993	
	Vaterunser (Gounod) Frau Sutter Durbetzki	994	12611
	Bunte Bonnie Lassie (Harlamoff) L. Bollanin	995	12621
	Bulbka mory (Bernard) G. Bollanin	996	12622
	German Lesson #12		G. L. 12
	Sprachgesang (Bernard) Czech (J. Bill) St. Olewski	997	12635
	Zigeuner Lied (R. Kretzer) St. Bolesski	998	12636
	Polen Tondichter (R. Jarecki) St. Bolesski	999	12637
	O Jungen Frisch (Bernard) St. Olewski	1000	
	Chiome! St. Moniuszko St. Olewski	1001	
	Zigeuner Lied (R. Kretzer) St. Bolesski	1002B	
	Chiome! St. Moniuszko St. Olewski	1003B	
	Bekt der Glückes (Bernard) Tannhauser (Wagner) Reimann	1003C	
	Aus der Traviata (Verdi) Bernard Reimann	1003	
	" "	1003B	
	Ich kettenmir in meinem Herzland (Bassen) Hofmann	1004	
	Ständchen Troubadour (Verdi) A. Werner	1005	
	Gretel Pinsch. Jenkins (Lortzing) Johnson	1006	
	Aus der Traviata Tiernay (Verdi) Bernard Reimann	1006C	
	Carmen Glöckchen (Bizet) Hofmann	1007	
	Chiome! St. Moniuszko Bolesski	1008	
27	Sol. from Estrella Bd.	1008	72
	Artist's Life Waltz	1009	7
	Sol. from La Traviata	1010	77
	Sol. from Huguenots	1011	78
	Soldiers in the Park	1012	79

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30	Sol. La Huguenots Bd.	1011B	78B
	Soldiers in the Park "	1012B	79B
	Sol. from Attila "	1013	66
	Sol. from Estrella "	1008B	72B
	Sol. from Attila "	1013B	66B
	La Bayamesa Var.	627B	12136B
	Nigger Fever Mezz.	1014	2809
	Nightingale & Frogs "	1015	2810
	Irish Reel "	1016	2806
	" "	1016B	2806B
	Blue Bird Polka "	1017	7168
	Nightingale & Frog "	1015B	2810B
	Sol. La Huguenots Bd.	1011C	78C
	Sol. Estrella "	1008C	72C
	Darkies Jubilee Mez.	1018	2802
	Blue Bird Polka "	1017B	7168B
	Nigger Fever "	1014B	2809B
	Darkies Jubilee "	1018B	2802B
	Nigger Fever	1014C	2809C
	Nightingale & Frog "	1015C	2810C
	Irish Reel "	1016C	2806C
	Blue Bird Polka "	1017C	7168C
	Ethiopian Bouquet Sio	1019	7574
	Manzanillo "	1020	7668
	Story Teller Waltz "	1021	7233
	Fairhill Schulman "	1022	7234
	Home Sweet Home "	1023	
	Nearer My God "	1024	8022
	Dem Polka Mez.	1025	2804
	Darkies Jubilee "	1018C	2802C
	Dem Polka "	1025B	2804B
	Home Sweet Home Sio	1023B	
	Nearer My God "	1024B	8022B

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Jan.

21	Ethiopian Bouquet	Lie	1019B 7514B
	Story Teller Waltz	Lie	1021B 7233B
	Chanzonille	"	1020B 7668B
	Rinkill Schulman	"	1022B 7234B
	Story Teller Waltz	"	1021C 7235B
	Nerson Minnelied	(Lenz) "	1026
	Oach auf Spanische		
	Serenade (Kreisler)	Schuman	1027
	Son O Longin - Die African		
	Sun (Engelhew)	Schuman	1028
	" "	"	1028B
	Oach auf - Spanische		
	Serenade	Schuman	1029B
	Es Flickt der Teufel		
	(Rubinstein)	"	1029
31	Darkey Volunteer	Oss	1030 7113
	Pretty Little Queen	"	1031 7264
	Son Toy Selections	"	1031A 7666
	Sounds from Africa	"	1032 2631
	Yankee Doodle	"	1033 2630
	Pretty Little Queen	"	1031B 7264B
	Sounds from Africa	"	1032B 2631B
	Salome	"	1034 7679
	Yankee Doodle	"	1033B 2635B
	Pretty Little Queen	"	1031C 7264C
	Es Blickt der Theu		
	(Rubinstein)	Schumann	1029B
	" " " "	"	1029C
	Oach auf - Spanische		
	Serenade	"	1029C
	Oach (Bentz)		
	Minnelied	Hofmann	1026B
4	Son Toy Selections	Oss	1031B 7666B
	" "	"	1031C 7666C
	Salome	"	1034B 7679B
	" "	"	1034C 7679C
	Darkey Volunteer	"	1030B 7113B
4	Postal Comique	"	1036 2527
	" "	"	1036B 2627B
	" "	"	1036C 2627C

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Jan.

	Sounds from Africa	Oss	1032C 2631C
	Yankee Doodle	"	1033C 2635C
	Darkey Volunteer	Oss	1030C 7113C
	Guarda Esta Flor	Ver	1024B 12204B
	Canionde el Ciego	"	12161B
	Gargoal Tactotum	"	12025B
	Los Rumberos Quieres	"	6264B 12210B
	" " "	"	6264C 12210C
	Gargo el Tactotum	"	12025
	La Ballina Ciega	"	12197B
	Himno Olas Mexicano	"	12169B
	El Torreador en Carmen	"	12209B
	Sobre Las Olas	"	1037
	" " "	"	1037B
	" " "	"	1037C
	Pretty Ladies	"	1038
	" " "	"	1038B 7905B
	" " "	"	1038C 7905C
	Othoa Bill	"	1039 7997
	" "	"	1039B 7997B
	" "	"	1039C 7997C
	McManus v. le Perrot	"	1040 8008
	" " "	"	1040B 8008B
	" " "	"	1040C 8008C
	Tell me Dusky Maiden	"	1041 8000
	Safe in Arms of Jesus	Lehmann	1042 3217
	Shina of Trinity	"	1043 3203
	Der Quack	Seiten	1044 12113
	Koenig Lear	"	1045 12191
	" "	"	1045B 12191B
	Das Deshale	"	1046 12111
	"	"	1046B 12111B
	200 Sheriah Lesson #2		S.S. 2

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Jan

8	Der Russisch-Seidn	1046A	12113 B
	" " "	1046B	12113 C
	Das Rattrichel	1047	12192
	" " "	1047A	12192 B
	" " "	1047C	12192 C
	An der Thür (Brunel) Dr. Porten	1048	
	" " "	1048B	
	Vergissmeinnicht - Zauberflöte Mozart	1049	
	" " "	1049B	
	" " "	1049C	
	Valentine - Faust Margarethe (Bonnet)	1050	
	Ohnmacht Blitz Donner rauschen (Hinche)	1051B	
	Jaakolka (Hj) Jarecki Olewski	1052	
	" " "	1052B	
9	Old Folkeat Home Ass.	1053	7340
	" " " "	1053B	7340B
	" " " "	1053C	7340C
	Raggy Raglans "	1054	7993
	" " "	1054B	7993B
	Bay State Quickstep "	1055	7955
	Madzenie (Ch. Lefin) Bolewski	1056	
	" " "	1056B	
	" " "	1056C	
	Edubryon by modzej (Ch. Lefin) Witzki	1057	
	Ohnmacht Blitz Donner rauschen (Hinche) Porten	1057B	
	Donner Donner Donner

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Jan.

13	Arlenda Melodie #1 (Melodie) Wooon Bd.	1175	35
	Loin de Bal Valz	1176	134
	Rotschenka L. Gollmann	1177	
	Oniedobry dzieweczynie (Hagerski) Dawski	1177B	
		1178	
		1178B	
14	Sonder mog Octavia (Samoiloff) L. Gollmann	1179	
	Sel. Bohemian Girl Bd.	1179C	68C
	Handel's Largo "	1180	117
	" " "	1180B	117B
	" " "	1180C	117C
	Dancing with me baby "	1181B	7722B
	" " "	1181C	7722C
	Loin du Bal Valz "	1176B	134B
	" " "	1176C	134C
	Traumerei "	1177	95
	" " "	1177B	95B
	Arlenda Melodie #2 "	1178	128
	" " "	1178B	128B
	" " "	1178C	128C
	" #1 "	1175B	35B
	" #1 "	1175C	35C
14	Wunderschön Jemitza L. Gollmann	1181	
	" " "	1181B	
	Ogi chorosho Bulachoff L. Gollmann	1182	
	" " "	1182B	
	Ogi nie platschi serotinka L. Gollmann	1183	
	" " "	1183B	
	Sonder mog Octavia (Samoiloff) L. Gollmann	1178B	
	Ich liebe Veilchen Bd. Clauss	1184	
	Jigeuner Baron Hofmann		
	" " "	1184B	
	Nellie Gray Tuson	1185	3615
	" " "	1185B	3615B

1902
Jan.

15	Nellie Gray Tuson	1185C	3615C
	Dudu "	1186	7987
	Ich liebe Veilchen "	1187	8024
	" " "	1187B	8024B
	" " "	1187C	8024C
16	Sally in our Alley Dunn	253	2208
	" " " "	253B	2208B
	" " " "	253C	2208C
	Sylvia Yorke Tuson	1188	3611
	Alle Tiere leben "	1188B	3611B
	Der Zigeunerbaron Hofmann	1184C	
	Ich kennt schwarz Augen zu lieben Hofmann	1183B	
	Unter den Lindenbaum (Oberle) "	1189	
	" " "	1189B	
	Reigenden Hirschen Gamsa (Herold) Porter	1190	
	" " "	1190B	
	Lied der Torero Carmen (Bizet) "	1191	
	" " "	1191B	
	Schwanenlied Lohengrin (Wagner) Hofmann	1192	
	" " "	1192B	
16	Wo uns traut Zigeunerbaron Walter Hofmann	1193	
	" " "	1193B	
	Unter dem Lindenbaum Hofmann	1189C	
	Apfelmus Blunk Hofmann	1207B	
	Frühmacher "	1207B	
	Frühlingslied (Gounod) Hofmann	989B	
	Komt spielt ich mit Liebe Zigeunerbaron Porter	987B	
	Der Stern (Strauss) "	1194	
	" " "	1194B	
	Pfeifchen Evangelimann (Kienzl) Hofmann	1195	
	" " "	1195B	
	Hab ich mich einst Kleid Dame (Suppe) G. Hofmann	1196	
	" " "	1196B	
	Bombastoriko Dame Goldmann (Brüll) Adams	1197	

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Jan

9	Nie wiem czy Gł. Niewiadomski-Chrzęki		1098
	" " "		1098B
8	Bombardenlied (Franz Grill)	Schumann	1099
	In Feld der Ehre Aufmarsch		1099D
	O dir und Ach in Liegendepfeife (Morgart)	Silvia	1065B
	Sacre du Printemps Marching (Bilder)	"	1098
20	" "	"	1098B
	" "	"	1098C
	Over to Bock Pheasant Bd.		1100 55
	" " "		1100B 55B
	Coronation March	"	1101 18
	" "	"	1101B 18B
	" "	"	1101C 18C
	Over to Bath of Seville	"	1102 7281
	" " "	"	1102B 7281B
	" " "	"	1102C 7281C
	Victorious America	"	1103 8033
	" "	"	1103B 8033B
	" "	"	1103C 8033C
	Mr. Thomas Cat	"	1104 7705
	Wedding of the winds Waltz	"	1105 7878
	" "	"	1105B 7878B
	Roosevelt's Roughriders	"	1106 133
21	Battle of Manassas Ov.		97 663
	" "	"	97B 663B
	" "	"	97C 663C
	" "	"	97D 663D
	After battle of Gettysburg Bd.		1107 110
	Liberty Bell March	"	1108 41
	" "	"	1108B 41B
	" "	"	1108C 41C
	Over to Bock Pheasant		1100C 55C
	El Miserere		1109 25

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Jan.

21	Trombone Sneeze Bd.		1110 8032
	" "	"	1110B 8032B
	Night Alarm	"	1111 49
	Mr. Thomas Cat	"	1104B 7705B
	Dixie	"	1112 21
	"	"	1112B 21B
	Semper Fidelis	"	1113 135
	Over to Merry Widow	"	1114 54
	Wedding of the Winds	"	1105C 7878C
	Trombone Sneeze	"	1110C 8032C
	Night Alarm	"	1111B 49B
	" "	"	1111C 49C
	" "	"	1111D 49D
	Roosevelt's Roughriders	"	1106B 133B
	" "	"	1106C 133C
	Victorious America	"	1103D 8033D
	Sally in our Alley Quar.		253D 2208D
	Kissing Km.		121 7784
	El Miserere Bd.		1109B 25B
	Bridge Quar.		144 2203
	"	" Capt.	144 2203
	When I think of you Mar.		1115 8001
	Child Chaser Dance Mar.		1116 7970
	" " "	"	1116B 7970B
	" " "	"	1116C 7970C
	When I think of you	"	1115B 8001B
	" " "	"	1115C 8001C
	" "	"	1115D 8001D
	Tosca Chicken le Cotty bombardien		914B
	" "	"	914C
	Bottes à disposition Mirette Bastatelling		910B
	Lasorotte e la studente Mirette Bastatelling		569B
	" "	"	569C

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Jan.

25	air de la vingtaine Samson et Dalila Saint-Saëns	826B		✓
	" " " "	826C		✓
	Noel Patern (Massenet) Bartel	674B		✓
	" " "	674C		✓
	romance Manon m'aimez (Massenet) Bartel	266B		✓
	" " "	266C		✓
26	Elle ne croyait pas Mignon (A. Thomas) Bartes	553B		✓
	" " " "	553C		✓
	Le Jardin d'Amour (Bizet) Bartel	677B		✓
	romance Sahanon Fedegue (Massenet) Bartel	278B		✓
	mon mirage Lombard (Alfonso Saint-Saëns)	537B		✓
	Ah Colombine Jouez pour moi amant Baisaire Bartes	835B		✓
	Ah Pierrot dans mes rêves (Massenet) Bartel	682B		✓
	air du vingtième Sharpe (Michel) Bartes	537B	[illegible]	✓
	Joseph	538B	Dreis Galeri	✓
	L'Orfèvre Midi mi mi Mazzoni	537C		✓
	Cavatina Faust (Gounod) Bartes	740B		✓
	Sweet 16 Louise Roberts	1119		✓
	" " " "	1119B		✓
	" " " "	1119C		✓
	" " " "	1119D		✓
27	My Julia Bake Minsky	1120		✓
	" " " "	1120B		✓
28	Aunt Dinah's home "	1121	8021	✓
	" " " "	1121B	8021B	✓
	My Julia Bake "	1120C		✓
	" " " "	1120D		✓
	Quand le dragon a bien trotté Sh. Dragons et Alliées Onnechel	986B		✓
	Si tu m'aimais (Donna) Bartel	857B		✓
	air du 20 Reto-Vaud Opposition de Valentine Meyerbeer	845B		✓
	Si tu m'aimais (Donna) Bartel	857C		✓
29	Cakewalkinite Sky-Minsky	1122		✓
	" " " "	1122B		✓
	Dis-moi vrai Bloomfield Sale	574B		✓

1902

	Angelo puro Dell'Acqua Alba Sala	905B		✓
	Dell'Acqua Duetto pon del fiero Midino	750B		✓
	" "	750C		✓
	Verse Margot (Doria) Bartel	1123		✓
	Verse Margot (Doria) "	1123B		✓
	" " " "	1123C		✓
	Guaramy Sento forza Midino	893B		✓
	" "	893C		✓
	Dinorah Ah vendetta assai Doria	1124		✓
	Sahanon a Dorée Dragone de Villers Onnechel	589B		✓
	Ebrea Rachele alzo da Giudea Midino	896B		✓
30	Guaramy Sento una forza Antonietta Midino	893D		✓
	Dinorah Le vendetta assai Doria	1124B		✓
	Manon (Puccini) Doria	755B		✓
	Re non Nella Midino	1125		✓
	Rossini Stabat Mater Cujus animam Midino	1125		✓
	Dylitana Lucia di Lammermoor Assoc.	747B		✓
	" " " "	747C		✓
	Sevillana (Alvarez) Cabello	939B		✓
	Dio non sarà Bella Amore Assoc.	1126	8014	✓
	" " " "	1126B	8014B	✓
	" " " "	1126C	8014C	✓
31	El Dominó Barcarola Cabello	869B		✓
	" " " "	869C		✓
	Manon (Puccini) Fra a voi Nella Midino	755C		✓
	Marino Alma mia Ofilia	802B		✓
	Don Jolia di Anieta La Colonna Cabello	791B		✓
	Lucia di Lammermoor Tombe degli avi miei Midino	628B		✓
	Bell'ed Marchina Ombra ed ostello "	705C		✓
	Manon Lescaut (Puccini) Sempre la stessa Midino	878B		✓
	" " " "	878C		✓
	Manon (Massenet) Oh Figura di Dolcezza "	703C		✓
	Oh Figura Petit Conte del Gallego Cabello	793B		✓
	Il Valzer del Passato Cabello	808B		✓
	Tacento			

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Jan

24	Conseyo Danza - Cabello	922B	
	Sevillana (Alvarez) "	939C	
	Marina "	802C	
	Alma mia Ofelia		
30	Guardi di Cammarano		
	Tomb degli Ant. Melino	698C	
	El brunlett		
	Barcarola Cabello	869D	
	Sacristia		
	Alvarez "	919C	
	Consejo		
	- Danza "	922C	
	" "	922D	
	Rossini, Stabat Mater		
	Aegina Animam Melino	1258B	
	Guardi di Cammarano		
	Tomb degli Ant. Melino	698D	
	Past & Future W. H. Kenny	1127 8030	
	" " "	1127B 8030B	
	Hard by a sailor "	1128 8011	
	" " "	1128B 8011B	
	" " "	1128C 8011C	
	Past & Future "	1127C 8030C	
	Oh, she lost it Fa.	1129 -	
	Forgotten Word "	1130 -	
31	Oh, she lost it "	1129B -	
	" " "	1129C -	
	Forgotten Word "	1130B -	
	" " "	1130C -	
	" " "	1130D -	
	Can't you take my word -	1131 8017	
	" " "	1131B 8017B	
	" " "	1131C 8017C	
	I got married this morning -	1132 -	
	" "	1132B -	
	Past & Future Kenny	1127D 8030D	
	Mocking Bird DAl	1133 -	
	Oh, she lost it Fa.	1129D -	
	Shepherds Dance Dal	1134 -	
	Mocking Bird "	1133A -	

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Feb

1	Mocking Bird DAl	1133C -	
	" " "	1133D -	
3	El Miserere Dal	7324 N	
	" " "	7324 N.L.	
	" " "	7324 N.	
	Shepherds Dance "	1134B -	
	" "	1134C -	
	Minnepara Jamboree -	1135 -	
	" "	1135B -	
	" "	1135C -	
	El angel Caido		
	Dundee - Duo Bak + Ber	1136	
	" "	1136B	
	Bach Gounod - Ave Maria		
	Lorraine Kind Hyman	1137	
	Old Christmas Carol		
	Kommen - Thompson etc. Schum	1138	
	" "	1138B	
	A.W. Dixon - Old Glory		
N.G.	Aya galen ray (K. Rhetzer)	9980 N.G. 8020	
4	Where the Silvery Colorado Lilly	1139 -	
	Darkey Volunteer Oca	1030C N	
	Where the Silvery Colorado Lilly	1139B 8020B	
	Dixon Old Glory - Wellhouse		
	Trompeter, etc. Schumann	1138C	
	Bach Gounod Ave Maria		
	Lorraine Kind Hyman	1137B	
	" "	1137C	
	Alex Porter Polka		
	Durchiguerbaron "	1084D	
	El Abb de Ave		
	Duo de los timidos Bak + Ber	1140	
	La Brava Dia		
	Otro de los toreros Cabello	926B	
	El Ave de Ave		
	Duo de los timidos " Ber	1140B	
	El Matrimonio		
	Jolla del Barracho Cabello	807B	
	Intermezzo		
	Lo que nunca pasa "	932B	
	" "	932C	
5	French Lesson # 1	F. L. 1 N.	
	" # 30	F. L. 30	
	" # 15	F. L. 15	

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French Lesson #26-27		A.L. 26-27
" " #20-21		A.L. 20-21
" " #28-29		A.L. 28-29
Barn Dance	Orch.	55 7724 A
" "		55B. 7724B
Birds & Brook	"	7860B
Musical Deceptions	"	555 A
N.O. Dodd	N.O.	555 B
Under Polar Star	"	629 A
Awakening of the Lion	"	657 A
" " "	"	657 C
" " "	"	657 D
Barn Dance	"	55C 7724 C
" "		55D 7724 D
Musical Deceptions	"	555 C
Birds & Brook	"	7860 C
N.O. Dodd	and upper part	7860 D
Under the Polar Star	"	629 B
Hearts & Flowers	"	7742B
" "	"	7742 C
Schubert's Serenade	Dbl	7192 A
" "		7192 B
" "		7192 C
" "		7192 D
Spring Song	"	7195 A
" "	"	7195 B
" "	"	7195 C
Polish Mark Dance	"	7325 A
" "	"	7325 B
Cav. Rusticana	"	6703 B
" "	"	6703 C
" "	"	6703 D
French Lesson #14-15		A.L. 14-15

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French Lesson #14		A.L. 14
" #18-19		A.L. 18-19
" 24-25		A.L. 24-25
N.O. Dodd 20-21		A.L. 20-21 B
" 22-23		A.L. 22-23
" 13		A.L. 13
" 12		A.L. 12
" 12B		A.L. 12B

Transferred to New Book

Notebook, N-98-06-30

This notebook covers the period June-July 1898. It was used by Ernest D. Kellogg as a logbook for meter tests. At the end of the book are several pages of undated notes by an unidentified experimenter relating to experiments on the heating of brass tubing. The front cover is labeled "Experimental Integrating Meter Reversing Electrolytic Mr. Kellogg(?) June 30-July 28, 1898." The pages are unnumbered, and the book has been used in both directions. Several pages have been removed from the book. Approximately 40 pages have been used.

Log of Meter Test.
started at 4.13 - A.M. Thursday.
June 30. 1898

Meter #1.

Start	Finish	Total Recorded	Total Left	Remarked
9.00-30	1.13-00		3.23-30	9 Comp.
1.13-00	4.45-30	3.33-30		
4.46-30	8.20-30		3.34-00	
8.20-30	11-49-30	3.29-00		
11.49-30	3.25-30		3.36-00	
3.25.30	8.26.00	5-00-00		5 Rain Contacts
8.26.00	12.18-10		3.52-15	
12.18-15	4.13-30	3.55-15		
4.13-30	7.56-00		3.43-30	
7.56-00	11.21-30	3.25-30		5 5
11.21-30	3.06-10		3.45-40	
3.06-10	6.18-30	3.12-20		Total ahead to amount on milk now used.
6.18-30				

Put C.P. on spinning electrodes in #1 + charged tripping lever. Restart at 9 P.M. July 7

9.26-10	12.21-30	2.45-20		Ten minutes for cutting down of charging cells.
12.21-30	3.22-45		3.01-15	
3.22-45	6.19	2.54-05		5 min. 10 sec. cutting down of charging cells.
6.19	9.10		2.51	
9.10	12.30	3.20		
12.30	3.00		2.30	(end)
	6.03	3.03		Pulling wire from

Time	Time	Right	Left	Remarks
9.07-30	12.20	3.12	3.[illegible]	Restart.
12.20	3.07	2.47	2.47	
3.07				Battery run down.
8.5-9	12.02		3.03	Restart.
12.02	3.07-30	3.05-30		
3.07-30				

Carbon Cathode — 9 n carbonate in solution.

8.23-00	A.m. 8.20-00	2.57-00		
8.20-00	11.02-30		2.42-30	
11.02-30	P.m. 1.45-00	2.42-30		
1.45-00	4.42-00		2.57-00	
4.42-00	7.36-00	2.54		
7.36-00	10.26-00		2.50	
10.26-00	A.m. 1.06-00	2.40		
1.06-00	4.02-00		2.56	
4.02-00	7.34-00	2.52		
7.34-00	9.44-00		2.50	
9.44-00	12.30-45	2.46-45		
12.30-45	3.26-00		2.55-45	

3.22-00	6.50-35	3.28-35		
6.50-35	9.25-00		2.34-25	Balance Carry
9.25-00 a.m.	6.15 A.m.	—		Caught
10.17-30	12.41-45		2.24-15	
12.41-45	3.12	2.30 15		
3.12	5.38-00		2.26	
5.38-00	8.05-30	2.27-30		Sent to H.Q.
8.05-30	11.17		2.11-30	
11.17	2.42	3.25		
2.42	6.34-30		3.52-30	
6.34-30				
Libs	Introduc	Cigarette	Punctu	
6.06	6.54	48		
6.54	7.43		49	
7.43	8.33-30	50-30		
8.33-30	9.38		64-30	
9.38	10.36	58		
10.36	11.14		38	
11.14	12.12	58		
12.12	1.05		53	
1.05	2.01	56		
2.01	2.53		52	
2.53	3.43	50		
3.43	4.37		54	
4.37	5.24	47		

Initials

Tests # 2. (1)

				Remarks
		Time		
		Rate - Left		
8.27-15	11.34-30		3.07-15	June 30th 1898
11.34-30	3.01-15	3.26-45		"
3.01-15	6.32-25		3.31-10	"
6.32-25	9.46-30	3.14-05		"
9.46-30	12.48-40		3.02-10	"
12.48-40	4.02-15	3:11-30		
4.02-15	7.12.15		3.12-15	
7.12.15	10.30	3 17-45		
10.30	1.55-15		3.25-15	
1.55-15	5.04-45	3.09-30		
5.04-45	8.12-30		3.07-45	
8.12-30	11.57-05	3:38-35		
11.57-05	3.05-20		3.18-15	
3.05-20	6.15-50	3.06-30		Copy taken with Edwards Steam Engine and recorded
6.15-50				
Both suspended & fixed electrodes C.T. gives.				
9.36	12.36-30	2.[illegible]-30	2.00-30	30 min. 1000 N changing cells
12.36-30	3.41-15	3.04-45	3.[illegible]	
3.41-15	6.46		3.02-05	30 min. 1000 N changing cells
6.46	9.40	2.54		
9.40	12.20-30		2.40-30	(end)
12.20-30	3.30	3.05-30		Bottom [illegible]

					(2)
Time	Trig	Right	Left	Remarks	
7.19	10.35	3.16	3.[illegible]		
10.35	1.50	[illegible]	3.15		
1.50	5.10-30	3.20-30	3.[illegible] -50		
5.10-30				Pattern dm	
8.37-30	11.51		3.13-30		
11.51	3.13	3.18			
3.13					
Cd. subplate - Cd electrodes.					
5.10-00	9.25-00 A.M.	4.15-00			
9.25-00	11.04-30 A.M.		1.39-30		
11.04-30	12.45-50	1.41-20			
12.45-50	2.25-00		1.39-10		
2.25-00	4.19-40	1.54-40			
4.19-40	6.30-00		2.10-20		
6.30-00	7.56-00	1.26-00			
7.56-00	10.02-00		2.06-00	Cd electrode fell + touched bottom	
10.02-00	7.25-30	3.23-30			
7.25-30	9.46-30		2.21-00		
9.46-30	11.40-45	1.54-15			
11.40-45	1.17-20		1.36-35		
1.17-20	4.34-30	3.21-10			
4.34-30	6.05-00		1.26-30		

				(4)	
9.11-30	10.03	51-30			
10.03	10.08		8-5		
10.08	11.53	5-5			
11.53	12.46		5-3		
12.46	1.38	5-2			
1.38	2.31		5-3		
2.31	3.26	5-5			
3.26	4.21		5-5		
4.21	5.15	5-4			
5.15	6.06-30		51-30	Cars begins to run	
6.06-30	7.03-30	54-30			
7.03-30	[illegible]				
[illegible]	[illegible]	[illegible]			
9.25-10	10.25		56-60		
10.25	11.06-15	41-15			
11.06-15	11.53		46-45		
11.53	12.36	43			
12.36	2.05		89	Balance run out	
2.05	2.08	3-3			
2.08	3.45-50		47.50		
3.45-50	4.35	49-10			
4.35	5.17		42		
5.17	5.56	39			
5.56	6.36		40		
6.36	7.23	47			
7.23	8.08		45		
8.08	8.57	49			
8.57	9.47		50		

				(3)
6.05-00	7.38-00	133-00		
7.38-00				
Silver electrodes – Cyanides of K + Ag.				
10.11-30 P.M.	11.02-30	51.		
11.02-30	11.54-00		51-30	
11.54-00	12.43-00	49		
12.43-00 A.M.	1.28-00		45	
1.28-00	2.21	53		
2.21	3.12		51	
3.12	3.58	46		
3.58	5.45			Balance run out
5.45	6.27	42		
6.27	7.20		53	
7.20	8.15-30	55-30		
8.15-30	9.10		54-30	
9.10	10.04	54		
10.04	10.57		53	
10.57	11.55	58		
11.55	12.45		50	
12.45 P.M.	1.31	46		
1.31	2.26		55	
2.26	3.15	49		
3.15	4.10		55	
4.10	4.56	46		
4.56	5.46		50	
5.46	6.39	53		
6.39	7.30		51	
7.30	8.22-34	52-30		
8.22-34	9.17		[illegible]	

11.30	12.31		61
2.31	1.15	44	
1.15	2.15		60
2.15	2.38	42	
2.38	3.56		58
3.56	4.39	43	
4.39	5.36		57
5.36			

Battery #-3 (1)

Start	Finish	Rest	Rest	Remarks
12.13-15	3.30-30		3.17-15	
3.30-30	7.40-40	4.10-10		
7.40-40	10.59.45		3.19-05	
10.59-45	3.50-20	4.50-35		Discharge was interrupted
3.50-20	7.43.45		3.53-25	
7.43.45	1.37-15	5.53-30		
1.37-15	5.59-30		4.22-15	
5.59-30	11.35-40	5.36-10		
11.35-40	3.11-30		3.35-50	
3.11-30	7.06-30	4.55-00		Battery subject to a fall, Potassium Ferrocyanide
7.06-30				

Copper (suspended) electrodes plated with gold
2 mch. 10 dec. 18 hanging cells

2.13-30	6.47	4.31-30		
6.47	9.45-30		3.58-30	
9.45-30	2.59	5.13-30		
2.59	6.20		3.21	
6.20	12.04-30	5.44-30		
12.04-30				Battery down
10.37	2.42-30		4.05-30	Restart
2.42-30				Battery down

(over)

7.[illegible]	7.5[illegible]		39
7.[illegible]	8.43-30	52-30	
Reset			
11.32	12.35	67	
12.35	1.23		44
1.23	2.11	51	
2.11	2.24-30		3.4-30
2.24-30	3.45	56-30	
3.45	4.2[illegible]		40
4.2[illegible]	5.20	65	
5.20	5.55-30		38-30
5.55-30	6.5[illegible]	50-30	
6.5[illegible]	7.35		42
7.35	8.33-30	58-30	
8.33-30	9.15		41-30
9.15	10.12	57	
10.12	10.52		40
10.52	11.50-30	58-30	
11.50-30	12.35		44-30
12.35	1.30	55	
1.30	2.28		58
2.28	3.31	63	
3.31	4.26		55
4.26	5.24	58	
Return			
9.-30	9.45		63.30
10.45	11.30	45	

Reproduction of this copy is illegible and incomplete

Agitelectric RCN+AgCN solution #3.

Time	Trip	Right	Left	Remarks
4.00-00	5.40-00 A.M.		1.40-00	(2)
5.40-00	7.12-20	1.32-20		
7.12-20	8.54-20		1.42-00	
8.54-20	9.57-45	0.57-25		
9.57-45	10.31-30		33.45	
10.31-30	11.27-40	56.10		
11.27-40	12.10-30 P.M.		42.50	
12.10-30	1.10-00	59-30		
1.10-00	1.54-20		44.20	
1.54-20	2.52-10	57-50		
2.52-10	3.35-30		43.20	
3.35-30	4.31-15	60-45		
4.31-15	5.17-50		41.35	
5.17-50	6-12-30	54-40		
6.12-30	6.53-00		40.30	
6.53-00	7.46-00	53-00		
7.46-00	8.25-00		39-00	
8.25-00	9.21-00	56-00		
9.21-00	10.02-00		41-00	
10.02-00	10.57-00	55-00		
10.57-00	11.41-00		43-00	
11.41-00	12.43-00 A.M.	58-00		
12.43-00	1.32-00		51.00	
1.32-00	2.36-00	64-00		
2.36-00	3.34-00		58-00	
3.34-00	4.28-00	54-00		
4.28-00	5.24-00		51-00	
5.24-00	6.07-00	43-00		
6.07-00	6.52-00		45-00	(6.00)

9.05	9.50	46		(4)
9.50	10.30		39	
10.30	11.22-30	52-30		
11.22-30	12.01		38-30	
12.01	12.56	55		
12.56	1.36		40	
1.36	2.26	50		
2.26	3.08		42	
3.08	3.51	43		
3.51	4.29		38	
4.29	5.20	51		
5.20	6.00		40	
6.00	6.47-30	47.30		
6.47-30	7.25-10		37-40	
7.25-10	8.18-30	53-20		
8.18-30	8.57		38-30	
8.57	9.47-30	50-30		
9.47-30	10.26		38-30	Sunday
10.26	11.10	44		
11.10	11.57		47	
11.57	12.48	51		
12.48	1.27		39	
1.27	2.21	54		
2.21	3.03		42	
3.03	3.55	52		
3.55	4.45		50	
4.45	5.39	54		
5.39	6.20-30			
6.20-30	7.12	52-30	41-30	

6.52-20	7.50-00	58-00		(3)
7.50-00	8.27-30		37-30	
8.27-30	9.20-30	57.00		
9.20-30	10.04-00		43.30	
10.04-00	10.59-00	55-00		
10.59-00	11.39-45		40-45	
11.39-45	12.37-00	57.15		
12.37-00	1.18-20		41-20	
1.18-20	2.17-00	58-40		
2.17-00	2.58-30		41-30	
2.58-30	3.57	55-30		
3.57	4.32-30		40-30	
4.32-30	5.27-35	55-05		
5.27-35	6.05-00		37-25	
6.05	6.54	49		
6.54	7.34-20		40-20	
7.34-20	8.33	58-40		
8.33	9.16-10		43-10	
9.16-10	10.10	53-50		
10.10	10.57-45		40-45	
10.57-45	11.47	56.15		
11.47	12.32		45	
12.32	1.28	56		
1.28	2.21		53	
2.21	3.17	56		
3.17	4.05		48	
4.05	5.01	56		
5.01	5.45		44	
5.45	6.39-10	54-10		
6.39-10	7.20		40-50	
7.20	8.14-30	54-30		
8.14-30	9.05		50-30	

Test #4

				Remarks
			14	
5-10				
8.06	11-14		3.08	
11-14	2-27-20	3.13 20		
2-27-20	5-5-10		3.27-20	
5-5-10	8.48 45	2.53-35		
8.48 45	12.15-50		3.26-15	
12.15	3.35-40	3.20-00		
3.35-40	7.16-40		3.41-00	
7.16-40	11.01-30	3.46-50		
11.01-30	2.27-30		3.26-00	
2.27-30	7.13-45	4.46-15		
7.13-45				

Changed only in fuses & bars.

9.46	12.50	2.04		(10 minutes off changing cells. 2 mins. 15 sec. off changing cells)
12.50	6.12		5.19-20	
6.12	8.59-25	2.47-25		
8.59-25	2.21		5.21-35	
2.21	6.25	4.04		
6.25	12.14-30		4.49 30	Quitting

11.30-30	11.35-40	58-15		
11.35-40	12.2 1		58-15	
12.2 1	12.25	58		
12.25	2.25		60	
2.25	3.25	60		
3.25	4.23		58	
4.23	5.12.30	54-30		

Silver electrodes - nitrate solution.

11.35	12.52-30	1.17-30		
12.52-30	2.17		1.25-30	
2.17	3.20	1.03		
3.20	4.40		1.20	
4.40	6.21-30	1.21.30		
6.21-30	7.08		46-30	
7.08	9.25	1.17		

Brass

				Suspended until broke, lent to T.H.C.
12.02	1.37-30	59-30		
1.37-30	2.05		63.30	
2.05	3.12	67		
3.12	4.10		58	
4.10	5.04	56		
5.04	6.03		59	
6.03	6.59	66		
6.59	7.50		51	
7.50	8.51	49		
8.51	9.51		60	
9.51	10.52	61		
10.52	11.52		60	
11.52	12.51-30	59-30		
12.51-30	1.55		63-30	
1.55	2.58	63		
2.58	3.59		61	
3.59	5.00	61		
5.00	6.01		61	

Tester — 8 —

Date	Time			Remarks
10.55-15	2.30-[illegible]			
2.30-15	6.12-30	8.42-15	3-34-30	
6.12-30	9.55-45		3.43-15	
9-55-45	1.44-50	3.49-05		
1-44-50	5.33.30		3.48-00	
5.33.30	9.24.30	3.51-00		
9.24-30	1.28-00		4.03-30	
1.28-00	5.27-15	3.59-15		
5.27-15	9.11-20		4.44-05	
9.11-20	1.08-15	3.56-55		
1.08-15	4.48-20		3.40-05	
4.48-20	8.39-30	3.51-10		
8.39-30				
Only [illegible] slides changed.				
9.10-35	12.50-00	3.29-25		Experimenter off during all
12.50-00	4.53-30		4.03-30	
4.53-30	10.04-50	5.11-20		
10.04-50	2.20		4.15-20	
8.17.15	12.16.15		4.11	Both down
12.16-15	5.48	5.29-41		
				Both down

3'

33
28
61

Trans	Trans.	Rafter	Left	Remarks
8.56	7.40	4.50		
2.06-30	6.45-30		4.36	
8.05-30	12.36	3.50-30		
12.36	3.05-6		3.08	

2.35	3.26		5-1	
3.[illegible]	[illegible]	4.44		
4.[illegible]	[illegible]		11.7	[illegible]
4.47	5.31	11.44		

Bitty # 6.

[illegible]	[illegible]			
8.37-00	8.57-00			
8.[illegible]	12.21-00	3-22-00	3.22-00	
12.21-00	3.49-30	3-28-30		
3.[illegible]-30	7.15-10		3.25-40	
7.15	10.00	3.24-50		
10.40-	5-23-15		3.43-15	
2.[illegible]	5-34.10	3.10-55		
5.36.10	8.57-30		3.22-20	
8.57-30	12-41-15	3.45-45		
12.41-15	4.27-15		3.46-00	
4.27-15	7.37-30	3.10-15		
7.37-30	11.25-45		3.48-15	
11.25-45	3.07-10	3.41-25		
3.07-10	6.14-10		3.07-00	registered with Amount only Letter stay [illegible]
6.14-10				
9.46	Interrupting long [illegible] 12.18-05	2.30-05		Terminal [illegible] long [illegible]
12.18-05	3.26-30		3.10-25	
3.26-30	6.28	2.59-200		
6.28	9.39		3.01	
9.39	12.19	2.50		

6.25-30	12.02	5.35-30	
12.02	3.12		3.10
3.12	6.21-30	3.09-30	
6.21-30	12.31		6.09-30
12.31	3.45	3.14	
3.45	7.27-30		3.42-30
7.27-30	11.15	3.47-30	
11.15	3.17		4.02
3.17	7.38	4.21	
Elt. [illegible]	[illegible]	Restart [illegible]	
5.05-30	5.50-30		42
5.50-30	6.30	11.05-30	
6.30	7.23		47
7.23	8.05	45	
8.05	[illegible]		41
8.50	9.35	45	
9.35	12.18		44
12.18	11.02	44	
11.02	11.48		46
11.48	12.36	48	
12.36	1.32		46
1.32	2.03	41	
2.03	2.55		52
2.55	3.41	45	
3.41	4.26	45	
4.26	5.12	46	
5.12	5.58		46
10.25	11.13-30	48-30	
11.13-30	12-00		46-30
12-00	12-45	45	
12.45	1.40		55
1.40	2.35	45	

		Right	Left	Remarks
12.19	3.28		3.09	
3.28	6.23	2.55	3.	
6.23	9.45-30		3.02-30	
9.25-30	12.28	3.02-30		
12.28	2.45		3.17	Batt. down
6.18-30	10.01	3.42-30		Restart.
10.01	12.1-30		3.20 30	
1.21-30	4.10-30	3.29-00		
Elt. [illegible]		Pump - 15 gr. [illegible]		
8.20				
1.35-45	4.19-40	2.43-55		
4.19-40	6.53-50		2.33-20	
6.53-50	9.37-00	2.44		
9.37-00	12.23-00		2.56	
12.33-00	3.47-00	3.14		
3.47-00	7.00-00		3.13	
7.00-00	9.05-30	2.05-30		
9.05-30	12.38-45		2.40-15	
12.38-45	2.29-30	1.50-45		Left S.G.E.
2.29-30	6.14		3.44-30	
6.14	9.06-45	2.52-45		
9.06-45	12.26-30		3.19-45	

Notes #7.

Ag Methods – Cyanide solution –

Time	Trig.	Reglit	Left	Remarks
5.25	6.12-30	47.30		July 19
6.12-30	7.04		51.30	
7.04	7.52	48		
7.52				

Acetate, Bromide edges – ~~Just dropped~~ KCl-Cyl Klegl 1-37-19

12.02-30	2.53		2.43-30	
2.36	5.44	2.52		
5.44	8.35-30		2.47-30	
8.35-30	11.46	2-10-30		
11.46	2.50		3.08	
2.50	5.53	3.03		
5.53	[illegible]		2.57-45	
8.57-45	2.29	3.36-15		
11.46	2.21	Morning	2.36	
2.21	5.36	3.15		
5.36	8.53		3.19	
8.53	12.30	3.35		
12.30	4.50		4.20	
4.50	9.31	4.41		
9.31	4.13		7.42	
4.13				

Titles #2 Ag electrode-Cyanide solution

Time	Trip	Potential	Left	Remarks
7.16	8.15	62		July 16.
8.15	9.22		64	
9.22	10.27	65		
10.27	11.28		61	
11.28	12.31	63		July 19.
12.31	1.41		60	
1.41	2.47	66		
2.47	3.45		61	
3.45	4.56	68		
4.56	5.57		61	
5.57	6.56	59		
6.56	8.03-30		64-30	
8.03-30	9.02-30	62		
9.02-30	10.01-30		59	
10.01-30	11.09	67-30		
11.09	12.15		69	
12.15	1.26	68		
1.26	2.32		66	
2.32	3.41	69		
3.44				

Light Cyanide — Aged Tripping Joints.

Time	Trip	Potential	Left	Remarks
10.50	1.45		2.46	July 25
1.45	2.23	2.41		
2.23	3.03		2.42	July 26.
3.03	10.11	3.06		
10.11	4.16			Discontinued
4.16	7.19-30		3.07-30	for week
7.19-30	10.14-30	2.55-1		
10.14-30	12.32-15		2.37-45	
12.32-15	3.30	2.37-45	~~3.30~~	Left to Tue
3.30	6.07		2.37	
6.07	9.12	3.08		
9.12	12.21		3.04	July 28
12.21	3.33	3.12		
3.33	6.43-30		3.10-30	
6.43-30	9.22	2.37-30		
9.22	12.00		2.38	
12.00	2.44	2.44		Left to Tue

[illegible] Sunset [illegible] - Sunset collection

2.41.11	8.23		3.71
8.25	8.03	2.38	
8.03	11.46		2.43
10.46	1.17-30	2.31-30	
1.17-30	4.12		2.37-30
4.12	6.47-30	2.31-30	
6.47-30	9.12		2.37-30
9.12	11.35-30	2.23 30	
11.35-30	2.05		2.29-30
2.05	4.45	2.40	
4.45	7.29		2.44
7.29	10.12	2.43	
10.12	1.15		3.03
1.15	5.02	3.47	
5.02	7.58		2.56
7.58	10.47	2.49	
10.47	1.45		2.58
1.45	5.19	3.34	
5.19	9.18		3.59
9.18	1.46	4.28	
1.46			

Sent to T.H.E.

Meter # 3

Time	Time	Reading	Cu. Ft.	Remarks
6.17	7.16	59		July 18
7.16	8.01-30		45-30	
8.01-30	8.56	54-30		
8.56	9.44		48	
9.44	10.38	54		
10.38	11.15		40	July 19
11.15	12.15	57		
12.15	1.18		58	
1.18	2.16	63		
2.16	3.10		56	
3.10	4.06	56		
4.06	4.54		48	
4.54	5.54	60		
5.54	6.34		40	
6.34	7.32-30	58-30		
7.32-30	8.14-15		41-45	
8.14-15	9.09	54-45		
9.09	9.48		39	
9.48	10.43	55		
10.43	11.26		43	
11.26	12.23	57		
12.23	1.00		37	
1.00	2.02	62		
2.02	2.45		43	
2.45	3.45	60		
3.45	4.30		45	
4.30	5.22	52		Sent to Lab
5.22	~~7.05~~ 7.03		~~58~~ 41	
~~7.05~~ 6.03	~~8.01~~ 7.01	58		
~~8.01~~ 7.01	~~9.11~~ 7.46	~~45~~	45	July 20
11.55	12.45		53	
12.45	2.01	73		
2.01	3.34		93	
3.34	5.10	96		
5.10	6.17		67	

Na_2CO_3 – $Ag\,K(Cy)_2$ – agate trip spring

11.44	1.02	1.05		spring July 23 – A. M. O.
1.02	1.42			In Mission
1.42	5.44		1.42	by Tech.

3 K_2CO_3 - $Ag_2K(Cy)_2$

Food	Urine	Right	Left	Remarks
5.44	7.35	2.31		
7.15	9.40		2.25	
9.40	11.15	1.35		
11.15	12.12		0.57	P.M.
12.12	1.47	1.25		
1.47	2.44		0.57	
2.44	4.21	1.27		
4.21	5.22-30		1.01-30	
5.22-30	7.02-30	1.40		
7.02-30	8.14-30		1.12	
8.14-30	10.00	1.45-30		
10.00	11.25		1.25	
11.25	12.28-30	1.33-30		
12.28-30	2.07		1.08-30	
2.07	3.56	1.49		
3.56	5.10		1.14	July 26
[illegible]	[illegible]	1.42-30		
[illegible]	1.28		1.26	
1.28	2.12	1.44		
2.12	3.34		1.22	
3.34	4.30	.56		
4.30	5.51		2.21	
5.51	8.14-30	1.23-30		
8.14-30	9.13		.56-30	
9.13	10.36-30	1.23-30		
10.36-30	11.34		1.23-30	
11.34	12.57	1.23		
12.57	1.36		.57-30	
1.36	3.15	1.20		July 26
3.15	4.28		.59	
4.28	5.35	1.10		
5.35	6.29		1.09	
6.29	7.50	1.21		
7.50	8.44-30		.54	
8.44-30	10.05	1.20-30		
10.05	11.22		.54-30	
11.22	12.51	1.31		
12.51	1.47		1.15	
1.47	3.16	1.29	.56	

3 K_2CO_3 - $Ag_2K(Cy)_2$

3.10	5.00		2.24	
5.00	6.48	1.48		
6.48	8.24		1.36	
8.24	9.31	1.19		
9.31	11.06		1.37	
11.06	12.11	1.25		
12.11	1.44-30		1.33-30	July 27
1.44-30	3.20	1.08-30		
3.20	4.37		1.37	
4.37	5.34	1.07		
5.34	7.13		1.39	
7.13	8.22	1.29		
8.22	9.47		1.25	
9.47	1.02-30	.57-30		
1.02-30	2.41-15		1.29-15	
2.41-15	3.23	.42-15		
3.23	5.20		1.21	
5.20	6.11	.57		
6.11	7.41-30		.30-30	
7.41-30	9.32-30	.57		
9.32-30	7.06		1.34	
7.06	8.[illegible]	1.07		
8.15	9.42		1.33	
9.42	10.54	1.08		
10.54	12.26-30		1.34-30	
12.26-30	1.37-30	1.09		July 28
1.37-30	3.12		1.34-30	
3.12	4.27	1.10		
4.27	5.57		1.35	
5.57				Mel. Arnold
				J. Forward

Trolley # 4

Agglutinoids - Cyanidized

From	Trip	Right	Left	Remarks
6.17	7.20		63	July 16
7.20	8.21	61		
8.21	9.22		61	
9.22	10.27	65		
10.27	11.31		64	
11.31	12.31	60		July 19.
12.31	1.39		65	
1.39	2.40	63		
2.40	3.40		58	
3.40	4.43	63		
4.43	5.47		64	
5.47	6.47	60		
6.47	7.43-30		56-30	
7.43-30	8.39	55-30		
8.39	9.35		56	
9.35	10.30	55		
10.30	11.26		56	
11.26	12.19	53		
12.19	1.13		54	
1.13	2.10	57		
2.10	3.07		57	
3.07	4.02	55		Sent to J.A.C.
4.02	4.58		56	
4.58	6.00	62		
6.00	7.01		61	
7.01	7.59	58		
7.59	1.12		68	Bott. down July 20
1.12	2.22	70.		
2.22	3.33		71	
3.33	4.43	70		
4.43	5.55		72	
~~12.27~~	~~2.39~~	~~Agl. Cl + Kry - again stopping~~	~~Jones~~	~~July 22 A.M.~~
12.27	2.12	2.12		
2.39	4.34		1.55	
4.45	10.34	1.49		
10.34	12.13		1.39	P.M.
12.13	1.57	1.44		
1.57	3.35		1.38	
3.35	5.11	1.36		

#4 KCl - Ag KCl(Ag)2

Time	Trig.	Right	Left	Remarks
5.11	7.03		1.52	
7.43	8.53	1.50		
8.53	10.44-30		1.55-30	
10.44-30	12.43	1.54 30		
12.43	2.41		1.58	
2.41	4.39	2.09		
10.22-30	[illegible]		1.44-30	
12.21	1.54	1.43		
1.54	3.21		1.40	
3.3	5.25			
5.25	6.9	1.49		
6.57	8.14		1.34	
8.14	9.44	1.44		
9.44	11.24		1.43	
11.24	1.07	1.42-30		
1.07	3.37		1.48-30	
3.37	[illegible]	1.45		
5.14	6.31		1.41	
6.31	8.21	1.49		
8.21	10.13		1.41	
10.13	11.57	1.42		
11.57	1.39		1.53	
1.50	3.20	1.30		
3.20	5.12		1.42	
5.12	5.40	.38		
5.40	8.48		1.08	
8.48	8.45	1.57		
8.45	10.32		1.54	
10.32	12.30	2.00		
12.30	2.40		2.01	
2.40	4.42	2.02		
4.42	6.58		2.01	
6.58	8.44	2.02		
8.44	10.27		1.43	
10.27	12.14	1.47		
12.14	1.37		1.43	
1.37	3.45	1.48		
3.45	5.37-30		1.32-30	
5.37-30	7.04	1.46-30		
7.04	8.58		1.54	

#4

8.58	10.32	1.57		
10.32	12.15		1.39	Giving off
12.15	2.05	1.50		
2.05	4.33		1.40	
4.33	6.03	3.59		
6.03	7.43		1.40	
7.43	9.35	1.52		
9.35	11.25		1.50	
11.25	1.17-30	1.52-30		
1.17-30	3.05-30		1.51	
3.05-30	4.55	1.49-30		
4.55	6.44		1.32	
6.44	8.33-30	1.40-30		
8.33-30	10.14-30		1.41	
10.14-30	11.58	1.43-30		
11.58	1.42		1.22	
1.42	3.30			
3.30	5.25		1.57	
5.25	7.08	1.55		
7.08	9.25		1.44	
9.25	11.57	1.45		
11.57	12.25		1.35	
12.25	2.10	1.35		
2.10	3.36		1.36	
3.36	6.57			
6.57	8.28	1.37		
8.28	10.06		1.38	
10.06	11.49	1.43		
11.49	1.43		1.54	
1.43	3.40	1.57		
3.40	5.35		1.55	
5.35				

Miles # 5 Ag Wednesday H Clarkston

Train	Train	Bright	Left	Remarks
7.06	10.40		3-34	July 16
10.40	2.11	3.31		July 19
2.11	5.16		3.05	
5.11	10.21	5.05		
10.21	3.41		5.20	
3.41				
[illegible]	[illegible]	[illegible]	[illegible]	
10.20	6.22 a.m.	7.56		July 27
6.22	12.47		6.33	July 5
12.47	7.06	7.09		
7.04	2.30		7.31	July 19
2.30	6.37-30	6.52-30		July 18
6.27-30	3.19		5.48-30	
3.19	6.03	5.38		
6.03	2.45		5.55	
2.45	6.12	6.24		
6.12	2.47-30		5.35-30	
2.47-30	8.25	5.37-30		
8.25	2.33		6.08	
2.33	8.55	6.25		
8.55	2.28		5.30	
2.28	3.04			

Meter # 6

Fig yesterday - Corrected solution

Time	Trip	Reg'd	Left	Remarks
6.15	7.06		51	July 1st
7.06	7.51	45		
7.51	8.37-30		45 30	
8.37-30	9.24	46-30		
9.24	10.08		44	
10.08	10.51	48		
10.56	11.42		46	
11.42	12.32	50		July 19.
12.32	1.22		50	
1.22	2.11	49		
2.11	2.58		47	
2.58	3.44	46		
3.44	4.19		35	
4.19	5.16	57		
5.16	5.57		41	
5.57	6.40	43		
6.40	7.23		43	
7.23	8.10	47		
8.10	8.49		39	
8.49	9.35	46		
9.35	10.15		40	
10.15	11.00	45		
11.00	11.45		45	
11.45	12.32	47		
12.32	1.12		40	
1.12	1.57	45		
1.57	2.37		40	
2.37	3.19	42		
3.19	4.01		42	
4.01	4.46	40		Sent to T.G.E
4.46	5.30		44	
5.30	6.17	47		
6.17	7.46			
7.46	8.34		48	Bath down
12.33	1.12	49		
1.12	2.01		49	
2.01	2.56	55		
2.56	3.35		42	
3.35	4.27	49		
4.27	5.16		52	

5.16-6.16 — .52

#6 K_2CO_3 - Ag $Ni(CN)_2$

Time	Time	Right 1144	Left	Remarks July 23 P.M.
4.58	6.46			
6.46	8.35		1.49	
8.35	10.25	1.59		
10.25	12.18		1.50	
12.18	2.07	1.49		
2.07	4.03-30			
4.03-30	5.58	1.54-30	1.56-30	
11.50	1.16	1.26		
1.16	2.51		1.35	
2.51	4.39			
4.39	5.39	1.26		
5.39	7.11		1.20	
7.11	8.25-30	1.32		
8.25-30	10.10		1.27-30	
10.10	11.29	1.27-30		
11.29	12.54		1.23	
12.54	2.21	1.22.5		
2.21	3.35		1.21	
3.35	5.30	1.25		
5.30	7.32		1.20	
7.32	8.45-30	.37		
8.45-30	10.35		2.08	
10.35	12.35	1.27-30		
12.35	1.46		1.20	
1.46	2.45	1.21		
2.45	3.30		1.19	
3.30	5.00	1.25		
5.00	6.06		1.16	
6.06	6.29	1.20		
6.29	8.05		1.23	
8.05	9.38	1.36		
9.38	11.14		1.33	
11.14	12.46	1.36		
12.46	2.21		1.32	
2.21	3.14	1.35		
3.14	5.20		1.33	
5.20	7.00	1.32		
7.00	8.37		1.34	
8.37	9.55	1.33		
9.55	11.03		1.32	

11.03	12.37		1.24	
12.37	1.57	1.20		
1.57	3.17		1.20	
3.17	4.37	1.20		Sent to T.A.C.
4.37	5.55		1.18	
5.55	7.23	1.28		
7.23	8.54		1.31	
8.54	10.21	1.27		
10.21	11.54		1.33	
11.54	1.23-30	1.29-30		
1.23-30	2.58		1.34-30	
2.58	4.31	1.33		
4.31	6.04		1.33	
6.04	7.30	1.26		
7.30	8.56		1.26	
8.56	10.10	1.20		
10.10				Missing data
			1.21	
2.16	3.37-30	1.21-30		
3.37-30	4.55-30		1.19	Sent to T.A.C.
4.55-30	6.14	1.17-30		
6.14	7.32		1.18	
7.32	8.45-30	1.17-30		
8.45-30	10.06-30		1.17	
10.06-30	11.26-30	1.18		
11.26-30	12.41		1.17.30	July 29
12.41	2.01	1.21		
2.01	3.18		1.16	
3.18	4.35	1.17		
4.35	6.02		1.27	
6.02	7.09	1.07		
7.09	8.24		1.15	
8.24	9.40	1.19		
9.40	11.02-30		1.19-30	
11.02-30	12.22	1.19-30		
12.22	1.45		1.23	
1.45	2.58-30	1.11.30		
2.58-30	4.12-30		1.16	
4.12-30				

No 9

In this table forty pairs of these areal now x 600 degr
Tabor and Hammerbs and now in
hour Empire Records

No 10

12.

224) 269 0
224
45
24
21
0

220	1302
234	183
228	223
214	222
229	231
239	236
231	1388

No 5

in old iron tube half full linseed oil ran to 600 degs and leaked could not find any of the bamboo fibre nor any sugar or gelatine

No 6

in iron tube half full of Castor oil ran to 600 and then leaked

No 7

in iron tube filled with powder carnauba wax ran to 600 degs and took out thermometer and ran 25 minutes longer and then it leaked

No 8

in iron tube filled half full of stearic acid ran to 600 degs and took out thermometer and ran half hour longer and no leak

250	197
270	199
295	233
336	262
345	215
1505	1106

1505

1106

1505

1106 / 1112 (1.01)

10

90

10

1

101

101

№ 1

Brass tube 3/32" wall half full Paraffine, ran to 550 Degs of heat and seam in tube opened

№ 2

Brass tube 3/32" wall half full of Castor oil ran to 600 degs of heat tube bursted seam

№ 3

Brass tube 3/32" wall half full of Boiled linseed oil ran to 575 Degs seam burst

№ 4

with old iron tube filled half full of paraffine ran to 600 degs and took out thermometer and ran 15 minutes longer and then it leaked

| | | |

14) 2737 (195.5

14
13
136
7

206
194
2) 400
200

191
197
2) 388
199.5

244
184
2) 404
202

206 . 45
194 05) 200
191 20
197 45) 199.5
189 30
218 35) 203.5
186 30
1381

181 15
211 10) 196
182 10
192 15) 187
205 15
187 45) 196
198 15
396
1381 L
2737

2) 392
196
188
182
2) 407
203.5
187

205
197
2) 392
196

ARTHUR E. KENNELLY NOTEBOOKS

These eight notebooks cover the periods 1887-1893 and 1894-1906. The first seven books contain transcriptions by Arthur E. Kennelly of material from the rough record books used by the experimenters in the Galvanometer Room. Included are notes, drawings, tables, and calculations regarding a variety of electrical experiments. The eighth book was used by Kennelly after he resigned his position at the West Orange laboratory. It also contains a one-page entry regarding Kennelly's return to West Orange to work briefly with Edison on x-ray experiments. A 57-page unbound index to the experiments has been filmed first.

Notebook #1

This notebook, which covers the period October 1888-July 1889, is a continuation of N-88-09-28. There are notes, drawings, tables, and calculations regarding a variety of electrical experiments, including tests of meters, octopolar dynamos, galvanometers, phonograph batteries, insulation, and the carrying capacity of various electrical conductors. There are physiological experiments using gasoline on bacteria and earthworms and electrocution experiments witnessed by Edison, Harold P. Brown, and members of the New York State Commission on Humane Capital Punishment. Also included are notes regarding the Brooklyn electrical distribution system; electrical resistance measurements for 39 employees of the laboratory and 220 employees of the Edison Phonograph Works, with information regarding their age, weight, and height; and theoretical notes concerning physics, electricity, and mathematics. Among the experimenters whose work appears in this book are E. C. Boynton, T. F. Lawrence, Theodore Lehmann, and Charles Wirt.

Notebook #2

This notebook covers the period July 1889-February 1890. There are notes, drawings, tables, and calculations regarding a variety of electrical experiments, including tests of meters, transformers, induction coils, insulation, and the carrying capacity of various electrical conductors. In addition, there are notes concerning the technical and commercial development of the Niagara hydroelectric power system and tests of motors for the electric railway, phonograph, and sewing machines. Also included are entries pertaining to the electrochemical treatment of arthritic conditions, Kennelly's account of an accidental electric shock he received, and theoretical notes about physics, electricity, and mathematics. Among the experimenters whose work appears in this book are F. P. Bergh, E. C. Boynton, Albert B. Herrick, and Theodore Lehmann.

Notebook #3

This notebook covers the period February-November 1890. There are notes, drawings, tables, and calculations regarding a variety of electrical experiments, including tests of meters, batteries, induction coils, the magnetic permeability of iron, the carrying capacity of copper wire, and the production of copper by electrolysis. In addition, there are notes and design drawings of electric railway motors, including experiments conducted at the Edison General Electric works at Schenectady, and of low-horsepower motors for fans, dental equipment, and the phonograph. Also included are notes regarding 3-wire electric power systems, lighting plans for the Lick Observatory, tests comparing a Westinghouse and an experimental Edison transformer, and theoretical notes concerning physics, electricity, and mathematics. Among the experimenters whose work appears in this book are Jonas W. Aylsworth, Reginald Fessenden, and Alfred J. Thompson.

Notebook #4

This notebook covers the period November 1890-June 1891. There are notes, drawings, tables, and calculations regarding a variety of electrical experiments, including tests of meters, batteries, induction coils, lightning arresters, and the carrying capacity of copper wire. In addition, there are extensive notes and design drawings relating to electric traction, including motor tests (some of these experiments were conducted at the Edison General Electric works at Schenectady), determinations of the tensile strength of trolley wire, and notes concerning the set-up of the experimental track at the West Orange laboratory. Also included are notes regarding low-horsepower motors and 3- and 5-wire electric power systems, tests comparing Edison's experimental alternators and a.c. motors with those of Westinghouse, and theoretical notes concerning physics, electricity, and mathematics. Among the experimenters whose work appears in this book are Alfred J. Thompson and Arthur Hoopes.

Notebook #5

This notebook covers the period June-December 1891. There are notes, drawings, tables, and calculations regarding a variety of electrical experiments, including tests of meters, condensers, fan motors, alternators, and dynamos. In addition, there are extensive notes and design drawings relating to electric traction, including tests of Edison General Electric street car motors, and data regarding low-voltage street railway systems. Also included are comparisons of Westinghouse, Thomson-Houston, and Edison transformers; data regarding the electromagnetic properties of iron; and theoretical notes concerning physics, electricity, and mathematics. Among the experimenters whose work appears in this book are Alfred J. Thompson and Arthur Hoopes.

Notebook #6

This notebook covers the period January-December 1892. There are notes, drawings, tables, and calculations regarding a variety of electrical experiments, including tests of meters, cable and cable insulation, batteries, and dynamos. In addition, there are extensive notes and design drawings relating to motors for phonographs, rock drills, and fans, including an alternating current fan motor design. Also included are notes regarding the alternating current electric power system in Newark, N.J., the electromagnetic properties of iron and nickel, physiological experiments on the effect of electric current on muscle action and blood flow, along with theoretical notes concerning physics, electricity, and mathematics. Among the experimenters whose work appears in this book are Alfred J. Thompson and Arthur Hoopes.

Notebook #7

This notebook covers the period December 1892-November 1893. There are notes, drawings, tables, and calculations regarding a variety of electrical experiments, including tests of meters, alternators, induction coils, transformers, batteries, and rheostats. In addition, there are extensive notes relating to motors for the phonograph, the kinetograph, and street cars and notes concerning replies by numerous central stations to inquiries from the Committee on Lightning Protection and the Committee on Grounding the Neutral of the Association of Edison Illuminating Companies. Also included is material pertaining to the technical and commercial development of the Niagara hydroelectric power system, conductor determinations, impedance and induction, and the electromagnetic properties of iron and steel, along with theoretical notes on physics, electricity, and mathematics.

Notebook #8

This notebook covers the period October 1894-February 1906. It was used by Kennelly after he resigned his position at the West Orange laboratory. There are notes, drawings, tables, and calculations regarding a variety of electrical experiments, including tests of motors, insulation, and photometers; conductivity tests of copper and aluminum wire; and meter and battery tests for the General Electric Lamp Works in Harrison, N.J. and the Edison Manufacturing Co. In addition, there is a one-page entry noting Kennelly's return to West Orange to work briefly with Edison on x-ray experiments. Also included are tests conducted with William Stanley and his associates in Pittsfield, Mass., on generators, transformers, and other equipment and 3 pages of notes relating to radio experiments conducted with Reginald Fessenden at Old Point Comfort, Va., Washington, D.C., and Brant Rock, Mass. Only the entry regarding x-rays has been filmed.

A.

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Kennelly Notebook #1

This notebook, which covers the period October 1888-July 1889, is a continuation of N-88-09-28. It contains transcriptions by Arthur E. Kennelly of material from the rough record books used by experimenters in the Galvanometer Room. There are notes, drawings, tables, and calculations regarding a variety of electrical experiments, including tests of meters, octopolar dynamos, galvanometers, phonograph batteries, insulation, and the carrying capacity of various electrical conductors. There are physiological experiments using gasoline on bacteria and earthworms and electrocution experiments witnessed by Edison, Harold P. Brown, and members of the New York State Commission on Humane Capital Punishment. Also included are notes regarding the Brooklyn electrical distribution system; electrical resistance measurements for 39 employees of the laboratory and 220 employees of the Edison Phonograph Works, with information regarding their age, weight, and height; and theoretical notes concerning physics, electricity, and mathematics. Among the experimenters whose work appears in this book are E. C. Boynton, T. F. Lawrence, Theodore Lehmann, and Charles Wirt. At the end of the book is a subject index (filmed at the beginning of the book). The front cover is marked "I" and "1888-1889." The book contains 168 numbered pages. Graphs and other items have been pasted into the book.

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E593.1-1

Record Book

of

Observations, Calculations, and Data in

The Galvanometer Building

Edison Laboratory

Commenced October 20th 1888.

Concluded July 28th 1889.

$$\frac{5.477}{167.5} = 3270 \times 10^{-6}$$

Assuming that $r = a + bt + ct^2$

these observations give

$$145 = a + 5.6b + 33.64c \quad (1)$$

$$96.6 = a + 20.2b + 408.04c \quad (2)$$

$$58.4 = a + 52.2b + 2724.8c \quad (3)$$

Whence

$$a = +170$$

$$b = -4.873$$

$$c = +0.04467$$

Meter Experiments

continued from Record Book no VI page 55.

October 18th Thursday.

Collected 750 c.c. of the last solution (10% by empirical record or 5.5% assumed of $ZnSO_4$ salt) and added 750 c.c. of H_2O distd. thus obtaining a 5% empirical or assumed 2.75% salt solution.

Before dilution the density was observed to be 1.043 @ 19.5°C

after - - - - - - - 1.023 @ 21.0°C by Hyd.

1.025 @ 21.0° . . balance

The tabular density of this solution is 1.014 @ 20°C. so that according to the tables our solution is finally in excess of its estimated strength.

The volume of liquid required to fill the tube was not in this case observed, as it was assumed to be fairly known from foregoing measurements as the following table shews:—

No. of obs.	Date	Method	Deduced Mean Area sq. cms	Estimated Weight of obs.	General Mean	Residual	v^2	Σpv^2	Probable Error
1	10.11	Calipers	5.402	1	5.477	0.135	0.018225	0.02258	± 0.0032
2	12.11	Volumetric	5.467	3		0.010	0.00010		
3	14.11	-	5.484	3		0.007	0.00005		
4	15.11	-	5.420	2		0.057	0.00325		
					5.477 ± 0.003				

The following measurements were made:—

Electrodes 167.5 cms apart.

No. of obs.	Time	Solution	Temp.	Bridge	Mass. thro battery	Mass. thro tube	T.Z. with load	F.Z. 0.3 deducted	t_{20} v.
1	9.35	5%	A 20° B 20.3	1000/1000 1500/1000	1	0.5	2976.7	2972.7	97.2
2	.37	≈ 2.75% $ZnSO_4 + H_2O$		0 . . .	4	2.0	2958.7	2952.7	96.86
3	10.05		A 52.2° B 52.1	- - -	4	2.0	1786.7	1785.7	58.40
4	11.30		A 54° & 62°	- - -	4	2.0	4447.7	4443.7	145.0

Volume Observations

No. obs.	Time	Level in A	Level in B	Sum A+B	Mean Temp	Diff level	Diff temp				
1	9.35	10.2	10.1	20.3	20.2°	4.1	32°				
2	10.05	12.2	12.2	24.4	52.2°	5.0	46.2°				
3	11.30	9.8	9.6	19.4	5.8°						

From this test we have the following observation equations

$$a + 5b + 25c = 34.26 \qquad 5a + 25b + 125c = 171.3$$
$$a + 12.5b + 156.3c = 27.23 \qquad 12.5a + 156.3b + 1953c = 340.4$$
$$a + 16.1b + 259.2c = 24.39 \qquad 16.1a + 259.2b + 4173c = 392.7$$
$$a + 26.4b + 697c = 19.51 \qquad 26.4a + 697.0b + 18400c = 515.0$$
$$a + 32.1b + 1030.4c = 17.52 \qquad 32.1a + 1030.4b + 33076c = 562.3$$
$$a + 39.2b + 1536.6c = 15.61 \qquad 39.2a + 1536.6b + 60236c = 612.0$$
$$a + 45.5b + 2070.3c = 14.00 \qquad 45.5a + 2070.3b + 94196c = 637.0$$
$$a + 52.2b + 2724.8c = 12.88 \qquad 52.2a + 2724.8b + 142237c = 672.2$$

(1) $$5a + 229.1b + 8499.6c = 165.46 \qquad 229.0a + 8499.6b + 354346c = 3902.9 \quad (2)$$

$$25a + 125b + 625c = 856.5$$
$$156.3a + 1953b + 24420c = 42,550$$
$$259.2a + 4173b + 67200c = 63,230$$
$$697.0a + 18400b + 485800c = 13,670.$$
$$1030.4a + 33076b + 1061000c = 18,050.$$
$$1536.6a + 60236b + 2361200c = 23,990.$$
$$2070.3a + 94196b + 4296000c = 28,980.$$
$$2724.8a + 142237b + 7426000c = 35100.$$

(3) $$8499.6a + 354346b + 15712254c = 131,184.5$$

So that the normal equations are

(4) $$8a + 229b + 8500c = 165.4$$
(5) $$229a + 8500b + 354400c = 3903.$$
(6) $$8500a + 354400b + 15,712,250c = 131,155.$$

From (4) $$a = -\frac{229b}{8} - \frac{8500c}{8} + \frac{165.4}{8}$$
$$= -28.63b - 1062.5c + 20.68$$

(5) $$= -229 \times 28.63b - 229 \times 1062.5c + 229 \times 20.68 + 8500b + 354,400c = 3903$$
$$= -6556.3b - 243,312.5c + 4735.7 + 8500b + 354,400c = 3903$$
(7) $$1943.7b + 111,087.5c = -832.7$$

(6) $$= -8500 \times 28.63b - 8500 \times 1062.5c + 8500 \times 20.68 + 354,400b + 15,712,250c = 131,155$$
$$-243,355b - 9,031,250c + 175,780 + 354,400b + 15,712,250c = 131,155$$
(8) $$111,045b + 6,681,000c = -44,625$$

From (7) $$b = -\frac{832.7}{1943.7} - \frac{111,087.5c}{1943.7}$$
(9) $$= -0.4284 - 57.15c$$

From (8) $$111,045 \times -0.4284 - 111,045 \times 57.15c + 6,681,000c = -44,625$$
$$-47,571.7 - 6,346,222c + 6,681,000c = -44,625$$
$$+334,778c = +2,946.7$$
$$c = +0.00880$$

$$b = -0.4284 - 0.5029$$
$$= -0.9313$$

$$229a = 3903 - 354,400 \times 0.0088 + 8500 \times 0.9313$$
$$= 3903 - 3118 + 7916$$
$$= 8701$$
$$a = 37.99$$

Proof. (4) $$8 \times 37.99 + 229 \times -0.9313 + 8500 \times 0.0088$$
$$303.9 - 213.3 + 74.8$$
$$165.4$$

Meter Experiments contd:— (2)

October 14th 1888

Since all the past series of observations with the zinc sulphate tube columns have been taken at or near three temperatures for the sake of a higher degree of accuracy viz— 5°, 20°, & 50° it was judged advisable to take one more series and in this to establish several maxima. At any temperature not a maximum or minimum it is difficult to prevent unequal heating except at the normal temperature, so that to produce more maxima reheating had to be successively adopted.

Took 500 c.c. of the original solution 100% arbitrary) or 55% Zinc assumed of density 1.336 @ 20°C and added 646 c.c. of distilled water to produce 1146 c.c. of 43.6% arbitrary or 24% assumed 2.50 solution tabular density 1.114 g. the observed sp. g: being 1.179 by balance @ 20°C. This solution was chosen because so far as can at present be judged it would be the strength advisable to adopt if the present existing strength of meter solution is to be changed.

Distance between electrodes 167.5. Observations as follows:—

No. of Obs.	Time	Solution	Temp.	Bridge	Resistance	Mag. Res. setting	Max. Res. Index	T. Z. Res. of Cells	T. Z. o.s. deducted	Sp. per.
1	11.50	43.6% ≡ 24% Zn	1 6 / 4.5° 5.5°	1000/1000	·	7	3.5	1049.7	1047.7	34.26
2	12.00		12.4° 12.6°	1000/1000		10	9.1	832.7	832.7	27.23
3	15.22		16.4° 15.8°	-		10	9.1	746.0	745.7	24.39
4	16.27		26.6° 26.2°	-		10	9.1	596.6	596.6	19.51
5	17.05		32.° 32.3°	-		10	9.1	535.7	535.7	17.52
6	17.20		39.° 39.4°	-		10	9.1	477.3	477.2	15.61
7	17.40		45.6° 45.4°	-		10	9.1	428.1	428.1	14.00
8	18.00		52.4° 52.0°	-		10	9.1	394.2	394.0	12.88

Assuming the empirical formula $r = a + bt + ct^2$ where r is the spec. res. of this solution at temp. t°C we have from the observations 1, 4, and 8 the observation equations

(1) $$34.26 = a + 5b + 25c$$
(2) $$19.51 = a + 26.4b + 697c$$
(3) $$12.88 = a + 52.2b + 2724.8c$$

from which

$$a = +38.92 \qquad 38.81 \text{ Dr. Lu.}$$
$$b = -0.978 \qquad -0.1772$$
$$c = +0.00917 \qquad 0.0001444$$

Meter Experiment contd:—
October 19th Friday

In Oxide Researches

To ascertain the effect of mercury alloyed with the zinc in oxidation, took a number of plates of pure zinc containing certain different percentages by weight of mercury in their composition. These plates were supplied by Lehmann under Wilmoski's directions. They were cast in the chemical laboratory from electrolytic zinc and with mercury practically pure. The plates as cast were {10 × 5·3 × 1·15 / 4" × 2" × 7/16"} and were made as follows.

2 plates of pure zinc
2 - - - - containing 1% Hg.
2 - - - - - 2% .
2 - - - - - 3% .
2 - - - - - 4% .
1 - - - - - 5% .

As each pair of plates was received in the Galvanometer Building it was stamped with a die indicating the % Hg. that there might be no subsequent confusion, the impression being made 8 times on each plate.

As these plates were somewhat heavy, they were all cut into quarters breadwise so as to produce 44 plates averaging {5·25 × 2·4 × 1·1 / 2 1/8" × 15/16" × 7/16"} thus exposing some 42·4 sq. cms total surface or when resting on a base vertically 39·6 . . say 40. They were roughly faced with a file and emery-wheel and after being sandpaped were washed in (1) dilute caustic potash and (2) distilled water. After drying, they were weighed by Lawrence. The weights are given below. Two (2,2) of the pure zincs were directly amalgamated to represent actual practice. After the weighing the plates were ranged symmetrically in a large beaker (covered) of meter zinc sulphate solution and set aside to develop oxide.

No. of Plate	% of Hg alloyed	Weight in air	No. of Plate	% of Hg alloyed	Weight in air	No. of Plate	% of Hg alloyed	Weight in air	% Hg	Mean Weight
0_1	0 amalgam	95·4927	4_1	4	97·6410	4_3	4	111·6600	0 am	96·8536
0_2	0 "	98·2144	4_2	4	93·8015	4_4	4	99·0824	0 am	88·0128
0_3	0 —	97·7266	5_1	5	101·2753	5_3	5	102·2170	1	95·1106
0_4	0	88·2990	5_2	5	99·6741	5_4	1	90·8382	2	97·5418
1_1	1	98·9323	1_3	1	92·2777	2_3	2	102·6340	3	97·1610
1_2	1	101·0243	1_4	1	92·4805	3_3	3	90·8365	4	100·5462
2_1	2	96·6619	2_3	2	95·1525				5	101·7221
2_2	2	97·9646	2_4	2	95·2960					
3_1	3	98·3149	3_3	3	98·9040					
3_2	3	101·2780	3_4	3	96·4714					

Zinc Sulphate solution.

Took over charge of manufacture of zinc sulphate solution, zinc plates and phonograph battery solution on 19th October 15 o'clock. Found in stock 5 carboys of solution each containing some 10 gallons, and some 30 lbs. of electrolytic zinc. Shipped 2 carboys to ~~York~~ Rochester same afternoon. Also in stock a barrel of zinc sulphate salt. Samples of this salt were tested on the 20th October and found to contain some iron and traces of arsenic. Decided to make use of this salt after removing the iron. Also made up some concentrated $ZnSO_4$ enough for about 30 gallons from the electrolytic zinc.

Wangemann brought two zinc plates on the morning of the 20th both of which were said to be 10% Hg alloy from the same crucible, and which were certainly used in similar solutions and for equal lengths of time in different cells. One of these zincs produced excessive heat to boiling. The other did not. On examination the former appeared the brighter of the two. Washed them. Specific gravities by Lawrence as follows:—

	In air	In H_2O	sp. gr.
That which did not boil the solution.	239.685	205.242	7.623
- - did - - -	216.278	188.008	7.651

No deduction could therefore be drawn from this source.

The solution in this case and for all the others all being once more 7.5 parts bn. thn. acid, 15. H_2SO_4 Conc. + 40 H_2O

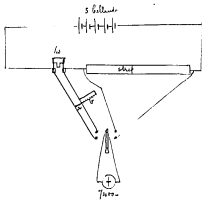
Meter Data supplied by Mr Wirt.

Meter Oxidation as found in practice

From Edgar's letter of May 3rd 88.

Nos	#16	#8	#4	#2	#1
(1) Number of cases	2	4	66	40	25
(2) Maximum	350 mgr.	185 mgr.	145 mgr.	80 mgr.	40 mgr.
(3) Minimum	345	150	50	20	15
(4) Average	348	170	90	48	28
(5) Table	400	200	100	50	25

Line #1 refers to the number of cases tested.
- #2 - - - maximum gain of the pos plate together
- #3 - - - minimum - - - - - - - -
- #4 - - - average - - - - - - - -
- #5 - - - usual no. number given in instruction book.



Meter Tests contd from page 3.
October 19th Friday.

After consultation with Mr Wint, decided to make up a standard meter, using a shunt of 0.1 ω and a resistance coil of about 98 ω.

Made up the coil as follows:—

Bare platinoid wire 0.0145 diam (0.018" # 26 BWG) was wound on a X spool. The ends were clamped under terminals. The resistance of the spool was observed three times.

1st at ordinary temp: 2nd at low temp in refrigerator
3rd - high temp in heater.

No of obs	Time	bridge	Res. std	leads	Res: spool	Temp	Diff Res.	Diff temp	Coeff per °C %
1	Noon	26.3°C 1000/100	98.1ω	0.02	98.12	26°C			
2	13.30	"	98.04	0.22	97.82	12.5°	0.30 (1.24)	13.5°	0.0226
3	14.00	"	99.88	0.22	99.36	90°C	1.54	77.5°	0.0203 } 0.0197

The best value is probably about 0.021 or 0.02 %.

x

The shunt was composed of german silver strip 5.6 cms wide and 0.033 cms thick as used for meters by Bergmann &c: the strip being given us by Mr Wint.

After adjustment, soldering, and fixing in a rough wooden box the res: of the strip was compared with that of a legal ohm and our bridge as follows.

By deflections as in figure: a 100 ω b 900 ω Def on Res: 205.2 On strip 205.2

Temp. legal ohm 22°C.		204.9	203.2
		204.6	203.0
	changed = 100 ω	208.5	205.7
	changed 200 b 1800	207.1	205.6

From best readings the strip $= \frac{1}{10} \times \frac{203.1}{204.75} \times 1.002 = 0.0994$ ω

By bridge 100% T. 25°C. Res: of shunt & leads 0.11852
- - leads 0.02062
0.0979 × 1.002 = 0.09808

Comparison by bridge of legal ohm and shunt.
100,000 ω = 98.57 ω uncorrected for T.B. 21.7°C.

$\frac{98.57}{100} = \frac{7}{1168}$

Res: of shunt and leads 0.11485
- - leads. 0.01932
0.09553

Meter Experiments contd—
October 21st Sunday.

With Mr Wilk aid made up five 25 light meter bottles as follows.

No. of Plate	Observed weight + paper disk	Observed weight of paper disk	Weight of plate	Sum of + and − plates	Observed weight of empty + disk	Weight of empty	Discrepancy	Mean Discrepancy	Adjusted Weights
	0·-	0·7290							
1	90·2210		89·4920	177·4300	178·1589	177·4299	−0·0001		89·4920
2	88·6670		87·9380						87·9380
		0·7290							
3	89·5477		88·8187	178·8687	179·5971	178·8681	−1·0006		88·8185
4	90·7790		90·0500						90·0498
5	85·8046	(assumed at) 0·7293	85·0753	173·0411	173·7693	173·0400	−0·0011	0·0005	85·0749
6	88·6951		87·9658						87·9654
		0·7293							
7	89·5058		88·7795	176·5217	177·2514	176·5221	+0·0004		88·7796
8	88·4715		87·7422						87·7423
9	85·3292		84·5999	173·0056	173·7346	173·9053	−0·0003		84·5998
10	89·1350		88·4057						88·4056

These bottles were labelled & set aside for meter use.

October 22nd Monday.

Repeated observations on the resistance of the shunt for the standard meter. Bridge 1000 : 100 (multiplying power 10) on legal ohm at 23.3°C.

No. of Obs	Res. of Artificial Gold	Res. in art. with Gold	Ratio in Bridge	Temp. of Legal Ohm	Res. of Legal Ohm at	Deflection on Shunt of Artificial Gold	Deflection on Shunt of Legal Ohm for meter Resist.	Mean Ratio	Res. of shunt
1	74·00	25.000	1000:100	23.2°C.	1·003	161·3			
2							158		
3						157·8			
4							156·9		
5					next page	158·8			
6							2·8 156·5	158·5 / 158·15	9.886×10^{-2}
7						158·5			
8							2·1 156·3	156·3 / 158·14	9.896×10^{-2}
9						158·3			
					Mean	158·85	156·93	156·9 / 158·9	9.904×10^{-2}
10			2000 : 200	23.4°	1·003	156·5	155		
11						156·5	155	155 / 157	9.900×10^{-2}
12						157·5			
13						157·0	155		
14									

Mean 9·8965

No. of mean	Result $\times 10^{-2}$	Method obtained	Estimated weight	General Mean	v	v^2	pv^2	Σpv^2	$0.6745\sqrt{\frac{\Sigma pv^2}{p(n-1)}}$
1	9·940	Deflections	3	9·899	0·041	0·001681	0·005043	0·147040	0·041142
2	9·981	Bridge	3		0·082	0·006724	0·020172		
3	9·55	Bridge	1		0·349	0·121801	0·121801		
4	9·897	Deflections	6		0·002	0·000004	0·000024		

Result 9·899 ± 0·041
= 0.0099 ± 0·0004 @ 23°C.
a probable error of 0·4%

Meter Experiments contd —

October 22nd Monday)

Resistance of platinoid spool wire (uncovered) wound on open spool before enclosed in box 98·088 @ 22·°C.

Tested the two 25 light meters as follows — (1) Shunts.

Deflection method.

No of Obs	Res. of Galv.	Res. in at with Galv.	Bridge Ratio on Ib	Temp Legal Ohm	Res. of legal ohm at temp	Deflection on legal ohm reduced to 1 ohm	Deflections on shunts of meter I A	Deflections on shunts of meter I B	Deflections on shunts of meter 2 A	Deflections on shunts of meter 2 B	Temp Meter	Mean Discrepancy
1	74·00	0	9909 : 100	23·5°	1·003	64·0	64·8 64·2	64·5 64·1	64		23°C.	
						63·6	~~64·4~~		64·1	64·0 63·9		
						63·5				63·9		
		From these deflections the mean resistances of the shunts would be:—					0·00104	0·01011	0·01010	0·01016		1·1%
		Resistances of spools by bridge after tightening up screws					8·041	8·121	8·079	8·121		

Placed bottle containing plates 3 + 4, 5 + 6 in meter #2 on a shelf above the steam pipes. Bottle # 1 + 2 was placed in the standard meter on a table in the outer room and bottles # 7 + 8, 9 + 10 were placed in meter #1 lodged in the refrigerator with the thermostat arranged to switch in a lamp at 4°C. All these 3 meters were joined up in series with an ampère-meter and resistance. They were set to work on the 113 volt circ. at 114·49 the current being 3·8 ampères steadily maintained.

Oxide experiment carried out by Lawrence.

Two small widemouthed stoppered glass bottles each holding rather more than 200 c.c. were procured and cleaned. Into bottle #1 cold meter Zn Sol. solution (and poured of density) by balance 1·0603 @ 22·°C. Into the other bottle #2 the solution was poured when hot after having been raised to {82°C (180°F} gradually) in a flask in order to expel the dissolved air. Two zinc plates with the copper rods removed were placed in each bottle. These weights of these plates were as shewn in the following table. The plates were 25 light ones lately amalgamated by Mr Watt, and of bright appearance.

No. of plate	Weight of plate + disk	Weight of disk	Weight of plate	Weight of plain	Weight disk of plain + disk	Observed weight of pair	Discrepancy	Mean Discrepancy
1	81·8852	0·7332	81·1520	162·5138	163·2474	162·5142	+ 0·0004	0·00045
2	82·0950		81·3618					
3	81·8990		80·8658	165·0585	165·7922	165·0590	+ 0·0005	
4	84·9259		84·1927					

Meter Experiments contd :-
October 22nd Monday

With the view of having at command a compensation for the temperature error of the meter solution, took 3 samples of cotton covered iron wire from reels in the stock room and wound them on open wooden X spools. Measured the res: of these at 3 different temperatures. Also repeated the measurement of that sample of nearly pure iron wire brought by Mr Watt the temp: coeff: of which sample came out so low on the 16th inst.

Dimensions

No. of sample.	Length	Condition	Wire diam: inches	B.W.G.	Wire diam: cms.	Areas sq. cms.	Areas / Length.		
1	575	bare	0·035"	20	0·0889	0·006207	1.080×10^{-5}		
2	800	cotton covered	0·022	24	0·0559	0·002456	3.067×10^{-6}		
3	700	" "	0·022	24 weight 25	0·0559	0·002456	3.067×10^{-6}		
4	700	" "	0·012	30	0·0305	0·0007306	1.044×10^{-6}		

Specific Resistance

No. of obs.	Bridge	Res: @ 21° C	Corrected to 0°	Sp. res.	Bridge	Time Ratio	Balance	Res: @ 21° C	sp. res.
1	1000/10	1·057	0·9459	10.2×10^{-6}	1000/100	99·6	1·050	1·0534	1.1383×10^{-6}
2	1000/10	4·817	4·320	13.25×10^{-6}	"		4·791	4·810	14.752×10^{-6}
3	"	4·570	4·211	12.92×10^{-6}	"		4·540	4·560	13.9857×10^{-6}
4	"	1·020	—		"		1·020		

Temperature Coefficient

No. of sample	Temp: in Refrigerator	Res: obtd. lands deducted	Temp: of air	Res: obtd. lands deducted	Temp: of incubator	Res: obtd. lands deducted	coeff: for low to mean temp.	coeff: for mean to high temp.	coeff: for low to high temp.
1	7°	0·979	21°	1·057	118°	1·840	0·53	0·57	0·57
2	7°	4·505	20°	4·817	138°	8·080	0·52	0·44	0·45
3	7°	4·330	21°	4·570	160°	7·900	0·39	0·39	0·39
4	7°	9·260	21°	12·18	103°	17·11	1·98 ?	0·42 / 152 / 145	0·42 ? / 153 / 145

Samples preserved.

Data supplied by Mr Wirt, taken from a paper by W. H. Preece in the Elect: World 17th Sept. 87

@ 60° F Iron's res: to Copper's Res. bears ratio of 6·034
Conductivity 0·982 of Matthiessen's standard
Temp. Coeff 0·48% per °C.

Laboratory Boilers. Boynton observer.

The load on the dynamos and engines reaching daily a maximum shortly before 18 o'clock, measurements were made on October 26th of the coal and water consumed by one Babcock and Wilcox double-furnaced boiler between the hours of 16 and 19 o'clock. During that time both Armington-Simms engines ran and also the Brown Engine. The level was maintained in the gauge, and the fires kept up. The boiler pressure indicated at 16 o'clock was 110 lbs

" " " " " 18 " " 65 "

" " " " " 19 " " 80 "

Steam was supplied to the heating pipes of all the buildings. The measured amount of water consumed was 18,200 lbs.

" " " " coal " " 2224

for 3 hours or per hour av. " " water " " 6070

" " " " " coal " " 741

Since by recent measurements it was found that 5½ lbs of coal and 49⅔ lbs of water were consumed per H.P. hour, the average activity of the boiler was by coal consumption 134

" " water " 122

The mean load on the Day circuit amounts being 225 HP

" " night " " " " 220 "

" " lamp-work " " " 40 "

485 "

The mean electrical load at 115 volts = 75 Elec. HP.

Allowing 16 HP to be supplied by the Brown Engine makes a total of 91 HP actually utilized, leaving 40 HP for heating of the buildings and losses in the dynamo shafting and dynamos.

A number of experiments were made with cylinders of wax and zinc suspended by thread vertically in zinc sulphate solution in the path of an electric current rising as high as 10 amperes with the view of ascertaining whether there were any increased or diminished friction on applying the current. The cylinder was caused to rotate by putting torsion on the thread and the time of one revolution under a certain amount of torsion noted with the current on and off. No difference could be detected. (27th to 30th October)

Tests of new pattern Grenet cell.

3 cells for the phonograph were designed by Mr Ott and were made as follows:—

A glass jar was filled to a convenient level with chromic acid solution. It was supported in a special cast iron stand and was closed by a lid movable up and down on a vertical slide rod fixed in the stand. The lid held a number of carbon rods in two rows clamped at the top & standing vertical, also a single zinc plate midway between and in plane parallel with the rows of carbon rods. By this means both the zinc and the carbons could be raised ~~xxxx~~ together from the solution.

Cell No	Internal Height	Internal Diam.	No. of carbons	Length of carbons	Length of zinc	Breadth of zinc	Thickness of zinc	Distance between zinc & carbons	Weight of zinc	Distance between rows of carbons
1	29	19	18	19.3	20.1	12.6	1.0	1.0	1828	3.3
2	20	16.6	14	20	14	10	1.0	1.0	987	
3	22	14.5	10	20	14	7.5	1.0	1.0	758	

Cell No.	At start			At end of 6th hour			At end of 12th hour			
	EMF	I.R.	C.	EMF	I.R.	C.	EMF	I.R.	C.	Duration of life above 2 amp
1	1.98	0.027	3.736	1.87	0.014	3.4	1.73	0.074	3.014	20.5
2	1.978	0.038	3.676	1.85	0.065	3.3	1.64	0.155	2.504	14
3	1.982	0.049	3.612	1.88	0.075	3.26	1.68	0.168	2.516	15

Corresponding quantities for ordinary Chromic acid cell small size

Cell No										
	2.05	0.10	3.3	1.97	0.11	3.25	1.90	0.28	2.4	13

These cells were set to work each on 0.50 platinoid strand at , having been charged with the usual solution whose formula is 7.5 part Chromic acid 15 part H_2SO_4 and 100 part H_2O. The curve sheet of the plotted observation is preserved. The noticeable feature of these cell is the low EMF due probably to the porosity of the carbons.

Curves of fall in the resistance of a 25 lb. main battery during the steady passage of one milliampère current.

The lines of the battery were at first prepared 1.3. and the fall is about 16 to 2.5 in 14 hours.

Find 4 curves the corresponding plot for a 2 milliampère current on the 1st.

Cover both sets curves corresponding to 4 ma.

Meter Experiments cont'd:—
October 23rd – 25th partly observed by Mr Watt, partly by Mr Hennelly.

A 25 lt meter bottle was taken which had been set up on the 5th inst. (p. 21 VI) when its res. was 1·3 ω, then set aside till the 12th; when a series of measurements was taken of its resistance (p. 48 VI) and since then remained untouched.

No. of Obs.	Date	Time	Time for state	Current	Bridge	Res. T.Z.	Leads	Res. of bottle T.Z.	Temp. bottle
1	88.10.23	15·00·	0·00	1 ma	100/10	16·20	0·22	15·98	23°C
2		·05	0·05			16·10		15·88	
3		·10	0·10			14·60		14·38	
4		·15	0·15			13·50		13·28	
5		·20	0·20			12·70		12·48	22·5°
6		·25	0·25			12·20		11·98	
7		·30	0·30			11·70		11·48	22·5°
8		·35	0·35			11·20		11·05	
9		·40	0·40			11·05		10·83	
10		·45	0·45			10·65		8·43	
11		·50	0·50			10·10		9·88	
12		·55	0·55			9·35		9·13	
13		16·00	1·00			8·85		8·63	
14		·05	1·05			8·20		8·08	
15		·10	1·10			7·80		7·58	
16		·15	1·15			7·35		7·13	
17		·20	1·20			7·05		6·83	
18		·25	1·25			6·85		6·63	
19		·30	1·30			6·65		6·43	
20		·35	1·35			6·45		6·23	
21		·40	1·40			6·25		6·03	22·8°
22		·50	1·50			5·95		5·73	3
23		17·00	2·00			5·70		5·48	
24		·10	2·10			5·50		5·28	
25		·20	2·20			5·35		5·13	
26		·30	2·30			5·20		4·98	
27		·40	2·40			5·10		4·88	
28		·50	2·50			5·00		4·78	
29		18·00	3·00			4·875		4·66	22·8°
30	88.10.24	8·10	17·10			4·60		4·38	18·8°
31	·10.25	9·25	42·25			4·05		3·93	20·6°
32		16·00	49·00			3·20		2·98	21·0°

October 31st Wednesday observed by Mr Lawrence.

Weighed 4 pairs of plates 2 pairs of unvarnished and two pairs of each side varnished plates. 2 bottles raised to 80°C. in sand-bath before immersion, 2 bottles at ord. temp.

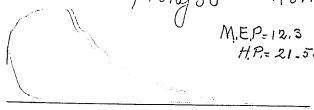
No. of plate	Weight of plate + disk	Weight of paper disk	Weight of plate alone	Sum of couple	Weight of couple + disk	Weight of couple alone	Difference now earth	Condition	Solution
1	88·6470	0·7327	87·9143	175·4118	176·1476	175·4149	+0·0031	plain	heated 100°
2	88·2302		87·4975						
3	87·2363	0·7300	86·5063	175·9096	176·6390	175·9090	−0·0006	plain	normal
4	90·1333	0·7300	89·4033						
5	90·2800	0·7309	89·5491	179·9690	180·7002	179·9693	+0·0003	varnished	heated
6	91·1505	0·7309	90·4199						
7	89·3413	0·7345	88·6068	177·3568	178·0910	177·3565	−0·0003	varnished	normal
8	89·4845	0·7345	88·7500						

N.B. It was noticed after 12 hours that the plates had been warmed were covered on their metallic surfaces with bubbles probably of air, a dense appearing on the varnished surfaces. Plates 1 2 5 + 6 in the solution that 3 4 7 + 8 showed only few or none bubbles

Activity of Engine at Phonograph Factory
November 1st 1888. Mr. Boynton observer.

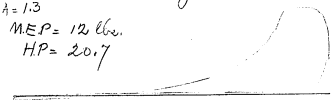
Total H.P. from two diagrams taken at 15 o'clock 44.74 } Mean 43.5
Porter - - - - 15.10 . 42.25 }
Boiler gauge 65 Revolutions 83.
Total H.P. at the corresponding date last month 33.

Rev. 83 Back ~~New Style~~
Pres 60 Time 3 PM
Spring 30 Nov. 1. 88



M.E.P. = 12.3 A = 1.83
H.P. = 21.55

Rev. 83 Front Old Style
Pres. 60 Time 3 P.M. Nov. 1. 88
Spring 40



A = 1.3
M.E.P. = 12 lbs.
HP = 20.7

Meter Experiment contd:—

Sunday 4th November.

Closed the meter test which has been going on since Oct: 21st the current having been passing through them from 7 to 12 and 12·30 to 1 o'clock daily since 14·4·9 22.11.88 see page 7. Removed the plates, dried, and weighed them with following results:—

No. of Plate	Weight of paper	Weight of dried paper	Weight of Plate dried	Sum of coupons	Weight of coupons	Weight of paper dried	Weight of coupons dried	Discrepancy	Probable value of plates dried	Probable value of coupons	Sum as check of probable weights
1	89·4237	0·7349	88·6888	177·4590	178·1945	0·7348	177·4600	+0·0010	88·6891		
2	89·5049	0·7347	88·7702						88·7705	177·4598	177·4596 / ·0397
3			88·0784	178·9166			178·9173	+ 0·0007	88·0786		
4			90·8382						90·8384	178·9171	178·9170 / 176·8861 / ·0289
5			84·3038	173·0845			173·0847	+ 0·0002	84·3039		
6			88·7807						88·7808	173·0846	173·0847 / 173·0840 / ·0007
7			88·0652	176·5623			176·5638	+ 0·0015	88·0657		
8			88·4971						88·4976	176·5633	176·5633 / 176·5231 / ·0277
9			83·8506	173·0618			173·0633	+ 0·0015	83·8511		
10			89·2112						89·2117	173·0628	173·0625 / 173·0021 / ·0890

Comparison of Weights

No. of Plate	Adjusted Weights 27.10.88	Adjusted Weights 4.11.88	Gain	Loss	Corrected Loss for shunt error	Mean Loss	Mean Temp.	Ratio Standard. Mean Loss	Ratio Normal Temp. / Your Temp.	% Error per °C	Mean Temp.
1	89·4220	88·6891		0·8029	0·5109		18°C.				
2	89·5350	88·7705	0·8325 / ·0296								
3	88·8185	88·0786		0·7399							
4	90·0498	90·8384	0·7886 / ·0487			0·7555	24·4°C Mile 42	1·073			
5	85·0749	84·3039		0·7710							
6	87·9654	88·7808	0·8154 / ·0411						1·033	0·19 % / 1% for 5°C	17·4°C
7	88·7796	88·0657		0·7139							
8	87·7423	88·4975	0·7583 / ·0411			0·7313	7·0°C. Mile 81	1·109			
9	84·3398	83·8511		0·7487							
10	88·4056	89·2117	0·8061 / ·0574								

Comparison of oxide &c.

No. of Plate	Gain in excess	Mean Gain in excess		Mean Percentage Loss of oxide with Plate 3 yrs	Mean Percentage loss of oxide with Plate Test 9 yrs	Mean Consequent Loss of bottle 3 yrs	Mean Consequent Loss of bottle Test 9 yrs	Ratio Mean oxide loss / Mean bottle loss	Inverse ratio	Calculated Corresponding Gain of bottle
2	0·0296	0·0296		10·736		(April 6·08.)	(April 7·02.)			(0·974)² = 0·948
4	0·0487	0·0466		10·73	12·09	2·65	3·87	1·347	0·7424	
6	0·04444									
8	0·0411	0·05444		~~10·09~~	~~3·50~~	~~3·00~~				= 10°
10	0·0574									

Meter Experiments contd:—
November 4th Sunday.

The two sealed bottles containing plates without zinc, mentioned on page 7 were unsealed and the plates withdrawn, dried and weighed. These the plates that had been left in bottle #2 containing heated solution had a distinct metallic lustre, while those in bottle 1 were on the contrary dull and oxydised. Results as follow:—

observations by Mr West

No. of plate	Simply	In pairs	Discrepancy	Adjusted value 31.10.88	Adjusted values 31.10.88	Gain	Loss	Loss gram of couple	Ratio of loss gram in tot. gram in cells		
1	81·2305	162·5400	-0·0003	81·2304	81·1519		0·0785				
2	81·3098			81·3097	81·3617	0·0520				Bottle #1 cold solution	
				162·5401	162·5136			0·0265			
3	80·8022	165·0789	-0·0007	80·8024	80·8660	0·0636			79·6	Bottle #2 Heated sol.	
4	84·2774			84·2775	84·1928		0·0847				
				165·0799	165·0588			0·0211	Reduction of 20%		

Judging from the figures which show that two plates have lost and two have gained it would seem that since the plates rested in contact in each bottle local action has taken place.

Two unamalgamated but cleaned zinc plates were immersed in solution that was first raised in the bottle to 84°C by means of a sand bath with the object of ascertaining whether they would throw off bubbles of gas in the same manner derived in the case of amalgamated plates. It was noticed on the following day however that no bubbles had formed but that the plates had become discolored — blackened — superficially. Weights observed by Mr Lawrence 3. 11. 88 before immersion as follows

No.	Weight + dish paper	Weight of paper dish	Weight of plate alone	Sum	Weight of sum + dish	Weight of sum only	Discrepancy	Adjusted weight simply	Adjusted sum		
9	81·9690	0·7350	81·2340	165·1188	165·8540	165·1190	+ 0·0002	81·2341	165·1190		
10	84·6195		83·8848					83·8849			

Bottle labelled and set aside.

Amalgamation measurement by Mr Lawrence.

To determine the change of weight brought about by amalgamation, two fifty-light plates were cleaned by Mr West but not amalgamated 4th Nov. Their weight on the 5th November was taken and they were then dipped in 10% H_2SO_4 for a few moments and amalgamated. The weight after drying were then repeated as follows:—

No. 1. before	176·1900	after amalgamation	176·0410	loss	0·1490
No. 2 .	176·5715	-	- 176·3980	-	0·1735
Mean	176·3808	-	- 176·2195	-	0·1613

In other words the plates seem to have lost more by dipping into the acid than they gained by amalgamation.

Motor Tests continued. Observations chiefly by Mr White.

Resistance of a bottle (25 lb) which had been set up on the 5th inst. and which has since remained untouched.

No.	Date	Time	Time from Start	Current	Bridge	Res TZ	Leads	Res. bottle TZ	Temp bottle		
1	88.11.3	14.05	0.00	2 mar.	not/10	20.90	0.22	20.68	23°C		
2		.10	0.05			18.30		18.08			
3		.15	0.10			15.20		14.98			
4		.20	0.15			12.00		11.78			
5		.25	0.20			10.50		10.28			
6		.32	0.27			9.20		8.98			
7		.55	0.50			7.25		7.03	22.4°		
8		15.00	0.55			7.00		6.78			
9		.10	1.05			6.50		6.28			
10		.21	1.16			6.20		5.98			
11		.30	1.25			5.95		5.73			
12		.45	1.40			5.80		5.58	22.5°		
13		16.00	1.55			5.50		5.28			
14		.30	2.25			5.15		4.93			
15		.40	2.35			5.00		4.78			
16	88.11.4	11.50	21.45			3.55		3.33	20°		
17	.11.5	8.10	22.05			3.40		3.18	13.8°		
18	.11.5	17.10	51.05			2.40		2.18	25.8°		

Transformer Experiments
November 5th Monday

Transformer running, at 1200 volts (approx) and 5.5 amperes on primary = 6500 Watts delivering about 50 amperes at 100 volts on secondary terminals = 5000 Watts. Fields supplied by 150 volt cell. After running for half an hour the highest temp reached by thermometer at armature periphery under cotton waste was 190°F = 88°C.

Meter Experiments continued. Observations by Mr Lawrence
November 5th Monday.

Amalgamated and coated with varnish on back and sides a number of plates to repeat the test of the three meters obtained during the last few days.

No. of Obs.	Weight of plate	Weight of sample	Sum of sample plate	Difference	Adjusted weight of plate	Adjusted weight of sample	Sum on check	Meter
1	87.1979	174.4362	174.4359	+ 0.0003	87.1980	174.4361	174.4361	Standard
2	87.2380				87.2381			
3	87.6246	170.0017	170.0010	+ 0.0007	87.6248	170.0015	170.0014	Meter #2 Normal temp.
4	82.3766				82.3766			
5	89.1536	176.4160	176.4156	+ 0.0004	89.1537	176.4159	176.4158	
6	87.2620				87.2621			
7	88.8450	not matched. Discarded.						
8	86.5613	173.7055	173.7051	+ 0.0004	86.5614	173.7054	173.7053	Meter #1 at low temp.
9	87.1438				87.1439			
10	86.2295	173.9805	173.9802	+ 0.0003	86.2296	173.9804	173.9804	
11	87.7507				87.7507			

Meter set to work at 17.0 o'clock at 3.75 ampere. #1 in the refrigerator and #2 at normal temperature.

Transformer Experiments contd:
November 6th 88.

Plain transformer. Commencing at 11.15

11.20	Volts on primary	1290	ampere	5.6	=	7220 Watt.		
	" " secondary	100	"	44	=	4400 "	60% eff.	90 lamp in cct.
.30	" " primary	1280	"	6.3	=	8060 "		
	" " secondary	99	"	50	=	4950 "	61.4%	108 lamp
.40	" " primary	1300	"	6.4	=	8220 "		
	" " secondary	100	"	49.5	=	4950 "	60.2%	" "

.45 Top carter carried away on transformer shaft and the fuzes of the municipal followed.

The above efficiencies are not very reliable since the Municipal wattmeter readings are at present in question.

On the arrangements necessary to illuminate 15, 60, 120 and 180 lamps from a Brush 30-light arc dynamo intended for 9.6 amperes, at 750 revolutions per minute.

Each municipal lamp of 20 cp has 6.6 ohms and needs 3.2 ampere or 21.1 volts.

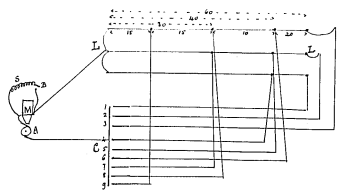
To light 180, 3 series of 60 lamps in parallel, voltage 1270, or 1373 at brushes with 9.6 amperes.

To light 120, 3 series of 40 lamps in parallel, voltage 845, or 900 at brushes with 9.6 amperes. To effect this a shunt of about 25 ohms but adjustable between 20 and 30 to be placed permanently across the field, reducing the current from 9.6 to $9.6 \times \frac{25}{36}$ or about 6 amperes thus (presumably) reducing the generated EMF from 1370 to $1370 \times \frac{6}{9.6}$ or 860

To light 60, 2 series of 30 lamps in parallel, voltage 635 or 700 at brushes with 6.4 amperes. To effect this the same shunt fixed at about 25 ω would be needed thus reducing the current from 6.4 to $6.4 \times \frac{25}{36}$ or 4.4 in the field and the EMF from 1400 to $1400 \times \frac{4.4}{9.6}$ or about 630, and taking saturation effect into account this would probably be 700.

To light 15 in series of 15 lamps, voltage 320 or 410 at brushes with 3.2 amperes. Without any shunt the current in the field being 3.2 the developed EMF would be over $1400 \times \frac{1}{3} = 470$ say 600. With the same shunt of 25 ω the current in the field would be reduced in the ratio of $\frac{25}{36}$ or the EMF would be about 420.

The requirements are therefore a plug board for making the necessary grouping and a magnet shunt up to 30 ω capable of carrying 5 amperes.



M Magnet
A Armature
S Shunt
B Switch
LL Series of lamps
C Commutator.

For	180	lights	plug in	1 2 + 3	disconnect	S.
"	120	"	"	4 5 + 6	connect	S.
"	60	"	"	7 + 8	"	"
"	15	"	"	9	"	"

Platinoid.

November 7th Wednesday.

100 feet of platinoid strip in 2 lengths gave following results @ 22°C.

No. of length	Measured length in metres	Breadth	Thickness	Area	11 mm Length	Bridge	Resistance	Cond.	Resist. of 1 ft	Spec. Res.			
1	27.462	5·64	0·0406	0·2306	8.25×10^{-7}	Wm. Jr. TB 23°C	0·5214	0·0125	0·5089	4.20×10^{-4}			
2	11.425	5·68	0·0406	0·2306	1.93×10^{-7}		0·2420		0·2295	4.24×10^{-4}			

Municipal Voltmeter test. at 23°C.

Coils 16,650	#1	In Potentiometer slide.	
25,670	#2	from initial terminal to extreme right	75·43
33,770	#3	- - - - 1400 mark	79·20
50,070	#4	- - - - {extreme right} 900	119·03

The calculation is $E = eR \div r + \frac{a\rho}{b}$

where E is the voltage to be measured.
e . . of the cell or cells attached
R . . resistance of the voltmeter at the time
r . . - from the initial terminal to the extreme right or 1500 mark.
ρ - - - between the limits of the slide.
b . . distance between these limits
a . . distance from the point of balance to the 1500 mark.

Here r = 75·4
b = 10·3
ρ = 43·6

∴ the divisor is $75.4 + a \times \frac{43.6}{10.3} = 75.4 + 4.23\,a$.

Taking 2 Daniell cells at 2·1 volts, the 1500 mark would correspond at the full limit of the machine to $\frac{2.1 \times 50{,}070}{75.4} = 1395$ say 1400 volts.

~~The carrying capacity of any cable is~~

Meter Experiments contd —
November 8th.

Took two wide mouthed bottles of about 200 c.c. capacity and placed a fitted pair of freshly amalgamated zinc 25 ct plates in each. Heated one bottle and its contained plates to boiling point over a sand bath, while the other was closed at the normal temperature. Each pair of plates was varnished on the backs and sides. On testing, the resistance of the bottle that had been boiled was about 70ω, that of the unheated bottle about 40ω. The plates of the heated bottle seemed to shew that varnish had been deposited on their faces in a thin layer. Both bottles were externally sealed with paraffine wax.

Took a 25 lt meter bottle whose zincs had been renewed but whose copper electrodes passed through the cork in the usual way. Found the res. (between the electrodes) of the films of $ZnSO_4$ incrustation within, or of moisture without to be exceedingly high (upwards 1Ω). The bottle had been prepared about two days previously and was well shaken up at that time but since then has remained untouched. On shaking up the bottle so as to thoroughly wet the corks on the inside, the resistance fell very much but at no time below 100ω rapidly rising as evaporation removed the internal film.

Resistance of an old 25 light bottle. observed by Mr Watt.

Took a 25 light bottle whose original resistance when made up on the 5th inst. was 1.3ω and measured the fall of resistance with a 4 milliamp current as follows —

No. of Obs.	Time	Time from start	Bridge	Current.	Res: Ω	Leads	Res less leads	Temp bottle or air round		
1	9·10	0.00	100/10	4 milliamps	9.0	0.22	8.78ω			
2	·15	·05			8.0		7.78ω			
3	·20	·10			7.0		6.78ω			
4	·25	·15			6·5		6.28ω	22.5°C		
5	·30	·20			6·3		6·08			
6	·40	~~·30~~			6·15		5·93			
7	·45	·35			5·85		5·63			
8	·50	·40			5·70		5·48			
9	·55	·45			5·55		5·33			
10	10·00	·50			5·40		5·18			
11	·10	1·00			5·20		4·98	21.8°C		
12	·20	1·10			5·00		4·78			
13	·30	1·20			4·85		4·63			
14	·40	1·30			4·65		4·43	22.5°C		
15	·50	1·40			4·58		4·28			
16	11·00	1·50			4·35		4·13			
17	·10	2·00			4·25		4·03			
18	·20	2·10			4·10		3·88			
19	·30	2·20			4·00		3·78			
20	·40	2·30			3·90		3·68			
21	·50	2·40			3·80		3·58			
22	12·00	2·50			3·70		3·48			
23	15·50	6·40			2·60		2·38	23°C.		
24	8·20	23·10			2·50		2·28	22°C.		
	9.11.98									

November 9th Friday.

A 25-light meter bottle was taken and filled with ordinary meter solution. Two unweighed plates well amalgamated, were connected and inserted. The bottle was then put on a sandbath and heated till the solution boiled. The heat was then removed, the lid screwed down tightly and paraffine was poured over the corks and stoppers. The resistance of the bottle shortly afterward when still hot, perhaps at 90°C was observed to be 0·57ω, slowly rising until at 23°C the resistance became steady at 4·32ω. It was then labelled and set aside.

Set up two meter bottles to stand for a week before inserting in meters. Weight (observed by Mr Lawrence) as follows:—

Plates No.	Position	Weight simple	Sum of couple	Observed weight of couple	Discrepancy	Adjusted simple weight	Adjusted weight of couple	Sum as check	Solution
1	vermilion	83·3256	172·1694	172·1690	+0·0006	83·3258	172·1688	172·1688	not heated
2	on back	88·8428				88·8430			
3	and	89·1486	178·4501	178·4502	+0·0001	89·1486	178·4501	178·4501	not heated
4	sides.	89·3015				89·3015			

November 10th Saturday.

Took the resistance of a number of bottles that have been made up at different dates and under different conditions as follows:—

No. of bottle	Date of setting up	Days at rest	Plates	Solution	Page of Record book	Resist. observed 10·11·88	Loss	Resist. of bottle 10·11·88	Current meas.	Bridge	Behavior	Temp.		
VI	31·10·88	10	plain amal	heated 6·88	11	2·6	0·1	2·5	10	100ω	Steady	23°C.		
VII	31·10·88	10	do. do	not heated	11	7·2	-	7·1	-	-	falling	-		
VIII	31·10·88	10	vermilion amal	heated 6·88	11	14·0		13·9	-	-	-	-		
IX	31·10·88	10	do. do	not heated	11	8·5		8·4	-	-	-	-		
X	3·11·88	7	plain amal	heated 6·88	14	3·4		3·3	-	-	-	-		
XI	7·11·88	3	vermil: amal	not heated	–	7·55		7·45	-	-	-	-		
XII	8·11·88	2	vermil: amal	heated 6·88	19	17·3		17·2	-	-	-	-		
XIII	9.11.88	1	plain: amal	heated 6·88	20	4·7		4·6	-	-	-	-		

Test of the chemical purity of the zinc sulphate salt employed for making meter solution. by Mr Lehmann

Iron 0·05 %.

Traces of Arsenic, Copper, Bismuth, and Lead.

Meter Experiments contd:-

November 10th Saturday.

Zinc & oxide res: readings by Mr Wirt.

Bottle D of 25 lt plates set up on the 5th October and left aside since that date was employed.

No of obs	Time	Time from start	Current	Bridge	Res: dead	lead	Res: bottle	Temp	
1	10.22	0.00	2 amp	1000/10	27	0.26	26.74	24°	
2	.23	0.00	8		16		15.74		
3	.24	0.01			7.5		7.24		
4	.25	0.02			6.0		5.74		
5	.26	0.03			5.55		5.29		
6	.27	0.04			5.15		4.89		
7	.28	0.05			4.90		4.64		
8	.29	0.06			4.75		4.49		
9	.30	0.07			4.55		4.29		
10	.31	0.08			4.45		4.19		
11	.32	0.09			4.30		4.04		
12	.33	0.10			4.20		3.94		
13	.34	0.11			4.10		3.84		
14	.35	0.12			4.05		3.79		
15	.40	0.17			3.97		3.71	24.2°	
16	.45	0.22			3.57		3.31		
17	.50	0.27			3.45		3.19		
18	.55	0.32			3.32		3.06	23.8°	
19	11.00	0.37			3.22		2.96		
20	11.10	0.47			3.07		2.81	23.0°	
21	.20	0.57			2.98		2.72		
22	.30	1.07			2.90		2.74		
23	.45	1.22			2.82		2.66		
24	12.00	2.07			2.26		2.09		
25	12.20	5.57			2.22		1.77	23.0°	
26	13.20	26.57			1.73		1.27	22.0°	

November 11th Sunday.

The E.M.F. of two new V Daniell cells for the Municipal voltmeter was (1) 1.093
(2) 1.083 @ 24° C.
sum 2.176 observed by Mr Lawrence 9.11.99

at this value the extreme reading of the instrument is

$$\frac{2.176 \times 50{,}070}{75.4} =$$

= 1445 volts. instead of 1500 as marked.

so that the instrument probably overindicates by 50 volts.

Meter Experiments contd.
November 11th Sunday.

Weighed after drying the plates enumerated on page 3 that have been standing since the 19th October i.e. 23 days: Air has had access to the bath (a large evaporating dish 18.2 cms diam 10.2 high filled to height of 6.9 cms i.e. area 260.2 sq.cms vol: liquid 1820 c.c.) during that time, a cardboard cover simply having rested on it to keep off the dust. The temperature having probably averaged 20° during the interval the density of the solution was observed to have increased from the original 1.05 to 1.07, and the reaction was slightly acid. Weights observed @ follows:-

Plate No	Weighed 19.10.88	% by weight of Hg	Weight before immersion 19.10.88	Weight after drying 11.11.88	Gains	Correction if any.	Gain corrected	Mean Gain.	General Mean.
1	O_1	0 but amalgamated	95.4927	95.5486	0.0559		0.0559	0.0507	
2	O_2	do do	98.2144	98.2598	0.0454		0.0454		
3	O_3	0	87.7266	87.7788	0.0522				
4	O_4	0	88.2990	88.3482	0.0492			0.0507	
5	1_1	1	98.9323	98.9970	0.0647				
6	1_2	1	101.0243	101.0761	0.0518				
7	1_3	1	92.2777	92.3277	0.0500			0.0544	
8	1_4	1	92.4805	92.5309	0.0504				
9	2_1	2	96.6619	96.7211	0.0592				
10	2_2	2	97.9646	97.0166	0.0520	96.9646	0.0520		
11	2_3	2	95.1525	95.2049	0.0524			0.0560	
12	2_4	2	95.2960	95.3543	0.0583				
13	2_5	2	102.5340	102.6920	0.0580				0.0576
14	1_5	1	90.8382	90.8934	0.0552				
15	3_1	3	98.3149	98.3745	0.0596				
16	3_2	3	101.2780	101.3370	0.0590				
17	3_3	3	98.9040	98.9588	0.0588				
18	3_4	3	96.4714	96.5360	0.0646			0.0596	
19	3_5	3	90.8865	90.8955	0.0590				
20	4_1	4	97.6410	97.7032	0.0622				
21	4_2	4	93.8015	93.8630	0.0615				
22	4_3	4	111.6600	111.7244	0.0644			0.0613	
23	4_4	4	99.0824	99.1417	0.0593				
24	5_1	5	101.2153	101.2847	0.0694				
25	5_2	5	99.6741	99.7470	0.0729				
26	5_3	5	104.2170	104.2872	0.0702			0.0708	
27	5_4								

These results show a steady increase of gain in weight with the % of mercury in the alloy. There was no perceptible difference in the appearance of the plates. It so happens that the three pure zinc unamalgamated plates gained on the average just as much as the two pure zinc amalgamated plates.

Weighed 3 other pairs of plates (connected by brass fitting) which have been in solution untouched since the 19th October, when weighed by White

No of couple	Date of immersion	Days left immersed	Condition	Weight before immersion	Weight after drying 11.11.88	Gain		
1	10th Oct.	32	(Amalgamated & varnished only on tops & ends)	172.707	172.8837	0.1767		
2			(Amalgamated & varnished everywhere except on faces)	172.062	172.2226	0.1606		
3			(Varnished over completely)	169.001	169.1704	0.1694		

From the lower table on the opposite page we have assuming a parabolic curve,

a	+	3.1b	+	(3.1)² c	=	4.3·15	=	a + 3.1b + 9.61 c	=	1.135
a	+	28.6b	+	(28.6)² c	=	37.75		a + 28.6b + 818 c	=	0.9996
a	+	25.8b	+	(25.8)² c	=	35.22		a + 25.8b + 665.6c	=	0.927
a	+	23.5b	+	(23.5)² c	=	35.88		a + 23.5b + 552.3c	=	0.9416
a	+	20.7b	+	(20.7)² c	=	35.13		a + 20.7b + 428.5c	=	0.924
a	+	17.9b	+	(17.9)² c	=	38.11		a + 17.9b + 320.4c	=	1.003
a	+	14.8b	+	(14.8)² c	=	40.76		a + 14.8b + 219.0c	=	1.073
a	+	11.7b	+	(11.7)² c	=	46.30		a + 11.7b + 136.9c	=	1.218
a	+	7.9b	+	(7.9)² c	=	53.56		a + 7.9b + 62.4c	=	1.521
a	+	4.1b	+	(4.1)² c	=	94.41		a + 4.1b + 16.8c	=	2.485
a	+	2.4b	+	(2.4)² c	=	170.0		a + 2.4b + 5.76c	=	4.474
a	+	15.8b	+	(15.8)² c	=	39.0		a + 15.8b + 249.6c	=	1.000

The normal equations are (regarding the first 10 as of the 10 series equal)

12a	+	204.2b	+	4436.3c	=	17.718		12a + 95.3b + 1439.4c	=	12.714
3.1a	+	96.1b	+	29.791c	=	35.18		96.1a + 29.791c		
28.6a	+	818b	+	23.394c	=	29.42				
25.8a	+	665.6b	+	17.173c	=	23.42				
23.5a	+	552.3b	+	12.974c	=	22.19				
20.7a	+	428.5b	+	8.870c	=	19.12		428.5a + 8870b + 183600c	=	396
17.9a	+	320.4b	+	5.735c	=	17.95		320.4a + 5735b + 128000c	=	321
14.8a	+	219.0b	+	3.112c	=	15.88		219.0a + 3.112b + 47.960c	=	235
11.7a	+	136.9b	+	1.602c	=	14.25		136.9a + 1.602b + 18.770c	=	167
7.9a	+	62.4b	+	4.93c	=	12.18		62.4a + 4.93b + 3.840c	=	96
4.1a	+	16.8b	+	.96c	=	10.19		16.8a + .96b + 2.532c	=	42
2.4a	+	5.76b	+	.16c	=	11.37		5.76a + .16b + .332c	=	26
15.8a	+	249.6b	+	3.94c	=	15.80		249.6a + 3.94b + 62.500c	=	250
(3)		95.3a	+	1439.4b	+	23.83c	=	116.74		1439.4a + 23.83b + 440.678c = 1533

(4)	8a	+	95.3b	+	1439.4c	=	13.72			
(5)	95.3a	+	1439.4b	+	23.83c	=	116.74			
(6)	1439.4a	+	23.83b	+	440.678c	=	1533			

From (4)

$$a = -\frac{95.3b}{8} - \frac{1439.4c}{8} + \frac{13.72}{8}$$

$$= -11.91b - 179.9c + 1.72$$

(5) $-95.3 \times 11.91b - 95.3 \times 179.9c + 95.3 \times 1.72 = 116.74 - 1439.4b - 23.83c$

$$-1135b - 17150c + = +116.7$$
$$+1439.4b + 23.83c = -163.9$$
$$7 + 3026b + 6689c = -47.2$$

From (7)

$$b = \frac{-6689c}{3026} - \frac{47.2}{3026}$$

$$= -22.0c - 0.155$$

(6) $-1439 \times 11.91b - 1439 \times 179.9c + 1439 \times 1.72 + 23.83b + 440.678c = 1533$

$$-17150b - 258,000c + 2475 \} = 0$$
$$+23.83b + 440.678c - 1533 \}$$
$$6709b + 181,778c + 942 = 0$$

$$-6709 \times 22.0c - 6.709 \times 0.155 + 181,778c = -942$$

$$-147,500c + 181,778c = -942 + 1040$$

$$\cancel{33,278c} = 1098$$

$$c = \cancel{+0.0033}\ 0.0302 \quad +0.002865$$

$$b = -22.0 \times 0.00287 - 0.155$$

$$= -0.063 - 0.155 = -0.219$$

(7) $95a = +1439 \times 0.219 - 23.83 \times 0.00287 + 116.74$

$$= 315.1 - 6.84 + 116.74$$

$$= 363.4$$

$$a = 3.814$$

(4) $8 \times 3.814 - 95.3 \times 0.219 + 1439.4 \times 0.002868 =$

Proof

$$30.5 - 20.87 + 4.13 = 13.76$$

$$1439 \times 3.814 + 23.83 \times -0.219 + 440.678 \times 0.002868 =$$

$$5489 + -5221 + 1264 = 1532$$

Sulphate of Zinc solution
Specific Res. and Temp. Coeff.

The following table gives a resume of the values obtained for the spec. res. near the 3 temps 5°, 20° & 50° for different strengths of solution. Then these assuming the empirical relation $\rho = a + bt + ct^2$ the values of a b and c are given.

No. of Obs.	Date	Density of Solution	Specific Res. observed @ 5°	20°	50°	Calculated values of a	b	c	Coefficients a	b	c
1	10th Oct 83	1·397 @ 20°	34·91	4·9	21·04	21·6	11·61	49·1	+ 4·315	− 1·323	+ 0·0138
2	11th . .	1·360 @ 20°	32·21	5·4	21·32	19·0	11·29	46·4	+ 3·775	− 1·089	+ 0·0118
3	11th . .	1·318 @ 24°	31·23	4·6	21·30	18·4	11·64	45·3	+ 3·522	− 0·963	+ 0·00795
4	12th . .	1·283 @ 16°	29·76	6·4	21·57	16·9	10·83	57·6	+ 3·588	− 1·023	+ 0·0104
5	12th . .	1·243 @ 23°	25·94	7·3	21·17	18·5	11·54	48·8	+ 3·513	− 0·920	+ 0·0089
6	14th . .	1·203 @ 21°	33·01	5·2	21·62	19·8	12·98	48·8	+ 3·811	− 1·035	+ 0·0102
7	15th . .	1·166 @ 22°	35·82	4·9	24·34	19·3	14·18	51·2	+ 4·0·76	− 1·052	+ 0·0104
8	16th . .	1·128 @ 19°	39·51	6·0	29·64	16·6	16·15	51·5	+ 4·6·3	− 1·207	+ 0·0121
9	17th . .	1·084 @ 21°	50·55	6·1	32·54	23·9	20·62	53·4	+ 5·8·56	− 1·383	+ 0·0126
10	17th . .	1·043 @ 20°	65·88	15·1	57·39	44·4	34·26	51·9	+ 9·4·41	− 1·89	+ 0·—
11	18th . .	1·025 @ 21°	14·5	5·8	96·6	20·2	58·14	52·2	+ 170	− 4·573	+ 0·0467
12	19th . .	1·17 @ 20°	34·24	5·0	19·51	26·4	12·88	52·2	+ 38·92	− 0·978	+ 0·00917
									+ 3·6·0	− 0·931	+ 0·0088

No. of Obs.	Calculated values of a	b	c	Coefficients a	b	c
1	1·00	1·00	1·00	1·00	1·00	1·00
2	1·11	1·32	1·57	1·57	1·21	1·57
3	1·12	1·11	1·21	1·21	1·11	1·21
4	0·97	1·17	1·32	1·32	1·17	1·32
5	0·91	0·97	2·36	2·36	0·97	2·36
6	0·92	1·04	1·13	1·13	1·04	1·13
7	0·99	1·05	1·18	1·18	1·05	1·18
8	1·05	1·07	1·11	1·11	1·07	1·11
9	1·05	1·13	1·13	1·13	1·13	1·13
10	1·12	1·23	1·32	1·32	1·23	1·32
11	1·50	1·40	1·37	1·37	1·40	1·37
12	1·54	1·65	1·63	1·63	1·65	1·63

The tabular % for sp. gr. 1·397 is stated at anhydr. $ZnSO_4$ 31 reckoned 31

1·360	28·6	0·7	27·9
1·318	25·8	1·0	24·8
1·283	23·5	1·8	21·7
1·243	20·7	3·1	18·6
1·203	17·9	2·4	15·5
1·166	14·8	2·6	12·2
1·128	11·7	2·4	9·3
1·084	7·9	1·7	6·2
1·043	4·1	1·0	3·1
1·025	2·4	0·8	1·6

Accepting the tabular figures we have.

No. of Obs.	Density of Sol.	Tabular % $ZnSO_4 + 7H_2O$	Tabular anh. $ZnSO_4$	% $ZnSO_4 + 7H_2O$ by calculation	% $ZnSO_4$ anh. by reckoning	discrepancy	coeff. a	ratio a standard
1	1·397 @ 20°	55	31	58·2	31	0·8	43·15	1·114
2	1·360 @ 20°	51·0	28·6	52·4	27·9	− 0·7	37·75	0·99
3	1·319 @ 24°	46	25·8	46·6	24·8	− 1·0	35·22	0·93
4	1·283 @ 16°	42	23·5	40·7	21·7	− 1·8	35·88	0·94
5	1·243 @ 23°	37	20·7	34·9	18·6	− 2·1	35·13	0·92
6	1·203 @ 21°	32	17·9	29·1	15·5	− 2·4	38·11	1·00
7	1·166 @ 22°	27·5	14·8	25·3	12·4	− 2·4	40·76	1·07
8	1·128 @ 19°	21	11·7	17·5	9·3	− 2·4	46·30	1·22
9	1·084 @ 21°	15	7·9	11·6	6·2	− 1·7	53·56	1·54
10	1·043 @ 20°	7·5	4·1	5·8	3·1	− 1·0	94·41	2·48
11	1·025 @ 21·8°	5	2·4	3·6	1·6	− 0·8	170·0	4·47
12	1·17 @ 20·0°	28·3	15·8	30·5			38·0	1·00

Rule for calculating the sp. res. of pure neutral $ZnSO_4$ of density less than 1·3 @ 20°C.

Find the density @ 20°C ... From this and Watt's tables find the % of anhydrous salt in the solution, let it be n.

Calculate $3{\cdot}8114 - 0{\cdot}219n + 0{\cdot}00287n^2$. Let it be p

Calling the temp °C t

$$\rho = p(38{\cdot}0 - 0{\cdot}931t + 0{\cdot}0031t^2)$$

Res. of Galv. 7935·5 (at 27·2)
@ 22·6 = 46·6 × 0·38 = 0·1748 × 7935·5 = 13·9

13·9
7935·6
2000.

2) 9938·6
6991 × 179 = 6991 divs corresponding to $\frac{1.429}{300,000} = \frac{1.429}{3 \times 10^5} = 0.476 \times 10^{-5}$

$= 4.76 \times 10^{-6}$ ampere

1 div $= \frac{4.76}{6.91} \times 10^{-6} = 0.69 \times 10^{-9}$ ampere $= 6.89 \times 10^{-10}$ c.c.

The current obtained in any experimental case through the galvanometer is $C/32,000 \times 10^3$ where $C = C \times 24.7 \times 10^{-3}$ =

$\frac{2.47\, C \times 10^{-3}}{3.28 \times 10^{-10}}$ ∴ $C = \frac{3.28}{2.47} C \times 10^3 = \frac{3.28 \times 6.89 \times 10^{-9} d}{2.47}$ where d. = defln

$= 0.915\, d.$

Octopolar Dynamo Test
November 12th Monday.

14·03 Started running Octopolar, exciting from 130 volt machine.
10 wires of overhead line in circuit, volts 100 ammeter 275 Deflection on Galvanometer 38 divs:
Constant of Galvanometer 300,000 6.1 K in cct with Galv. 2000 – Shunt
Defln 179 Temp. 22·6°C.
Increased wires to 18 and deflection to 63 divs.
This current heated the cables in the room to smoking temperature so cut it off about 14·35. Temp. 154° F.

15·03 Commenced running again. Zero reset.

·05	107	200	6	24	=	119 amp.	calculated.	
·07	103	320	10	37·5	=	343		
·09	98·5	410	13	46	=	421		
·11	105		16	63·8	=	584		
·13	101·5		20	72·5	=	663		
·15	97		24	83	=	759		750 revs
·18	92·5		28	89·8	=	822		76,000 Watts.
·19	90			87	=	796		
·21	88			83	=	760		
·25	84		30	80·2	=	734		
·35				79	=	723		
·42				73·5	=	672		
·53	75·5			73·5	=	672		

Shut down and took temp. of 204·5°F.
Altered engine governor to obtain a greater speed than the last 236.

16·09 Started engine speed 265 at driving wheel, and 850 at Dynamo.

·22	135 volts	430 amps. indicated	10 wires in cct.	Defl. 45·5	=	416	
·25	115		19	70	=	640	
·27	107		23	79·2	=	725	77,500 Watts

Temp of periphery of armature lost on this occasion.
No symptom of overheating wires on the poles or the connecting wires through the woodwork, the greatest current on each overhead circuit being 42 amps.
At the pressure of 100 volt, each overhead wire takes about 30 amperes.

Meter Experiments contd.

October 12th Monday.

Took down bottle containing 2 separate 25 light plates that have stood since October 22nd at the average temp: of about 20°C. Solution 1.054.

No of plate	Date of immersion	Date of emersion	Condition of plate (varnish measure)	measure.	Weight 22.10.88	Weight 12.11.88	Gain	Presumed Weight of Zinc (Mean of 2 plates)
1	22.10.88	12.11.88	Zinc not wet protected, not varnished on top or rod.	Amalgamated	86.5452	86.6112	0.0660	0.0616
2	-	-	Varnished - (not protected)	Not amalgamated	92.1340	92.2616	0.1276	

Measurement of the amount of Zinc sulphate in the solutions previously tested for specific resistance. by Mr Emmerson

3 specimens of solutions were taken on the 22nd October each just 50 c.c. by means of the sp. g. bottle, one of the original or 100% sol: one of the 30% sol. and one of the 5% sol. These specimens in weighed evaporating dishes were set aside to evaporate under muslin dust cover. The crystal residue and dishes were finally weighed on the 12th November.

No of No.	% Sol.	Weight of 50 c.c.	sp. g.	sp. g. by record. (by M. & Inness)	Weight of dish (11.11.88)	Weight of dish	Weight of crystal + $ZnSO_4$ + $7H_2O$	% by weight of crystal	% by table corresponding to sp. g. obtd.
1	100	69.7431	1.3949	1.396	82.2727	41.6250	40.6477	58.2	55
2	30	58.9513	1.1790	1.179	72.3620	54.3495	18.0125	30.5	28.3
3	5	51.0993	1.0220	1.025	83.9700	82.4030	1.5670	3.6	3.8

These numbers agree therefore very fairly with those given in the tables corresponding to the sp. g. observed. @ 20°C.

The Resistance of the Astatic Thog Galvanometer on the 5th table was observed at 2 temperatures on two successive days during the resuspension of the mirror as follows:—

No of Obn	Bridge	Res. obtd.	Leads	Res obtd. of Galvn.	coil L.T.B.	T. g.	T. B.	(1) calculated for (1)	calculated to 20°C.
1	1000/1000	7950	0.5	7949.5	7960.4	24.8°C	23.6°C		7815
2	"	8035		8034.5	8046.9	26.6°C. (by 2 thermms)	24.2°	8015.	7845
								Mean	7830 ± 20Ω

Res. of galv. 8034 = 26.5 Ω.

at 8000 = 20000 for multiplying power of 5.0

so that constant of 1.43 will and 300000 = gives galv. deflection

i.e. 1 div. corresponds to a current of $1.43 \times 10^{-5} / 9.00 \times 10^{7} \times 3.00 \times 10^{10}$

$= 1.43 \times 27 \times 10^{-15} = 5.3 \times 10^{-15}$

Octopolar Dynamo Tests
November 13th Tuesday

		Volts at Terminals	Symbol Wire in cct.	Amperes in Field	Ohmmeter Reading	Shunt Deflection			26 Amps. calculated
8.07	Commenced running Octopolar	133	3	21.5	160	28	53		
8.15	" " "	133	6	20.5	275	55	50		
.20		133	9	20.0	400	77	52		
.23		131	13	19.5	—	105			546
.25		127	16	19	—	125			620
.30		122	19	18.5		146			757
.31		119	20	18.5		152			790
.32		116.5	20	18.0		147			764
.33		113	21	17.0		150			780
.35		125	21	22.5		157			816
.37		119	21			147			764
.50		115	22			142			749
9.35	Speed of dynamo 817 revs.	113	24	19.5		148			770
.20		118	24	23		155			806
10.02		123	24	22.5		159			827
11.00		122	24	22.5		—			
11.02	Band nearest to pulley on armature carried away at a soldered joint. Stopped machine, and took temperature. Highest reached 298°F								

The load during the last two hours had been on the average $820 \times 122 = 100{,}000$ Watts.

The P.D. on the magnet coils (in 2 parallel set of 8) must have been at least 260 volts, and the current in each series being about 11.5 ampere = 2990 Watt ÷ 8 = 375 Watts per coil expended in heat. This continued steadily for 2½ hours steadily raised the temp. to about 170° F. As this was hardly fair to the armature it becomes necessary to consider the best method of rewinding the magnets in order to generate the same amount of magnetism with less heat. The machine to be selfexciting and to be allowed as much as 30 lbs of wire to each magnet coil. The present winding is 20 lbs of #15 BWG wire on each of the 16 coils.

The possible combinations to be considered are :-

(1) All 16 coils in series
(2) Two series of 8 each
(3) Four " " 4 "
(4) Eight " " 2 "
(5) Sixteen " " 1 "

It is required to find the winding for best effect.

The present No. of layers on each coil is 7.6, the number of turns to a layer 81

Total no. of turns 616.

Since 12 ampere has to be provided for, the total number of ampere turns on each coil must be 616 × 12 = 7300 nearly

$$r = \frac{v}{N \pi d} = \frac{130}{750 \times n \times 2{\cdot}1} = \frac{1{\cdot}30 \times 10^{1}}{n \times 7{\cdot}3 \times 2{\cdot}1 \times 10^{3}} = \frac{13{\cdot}0 \times 10^{-2}}{n \times 15{\cdot}33} = \frac{8{\cdot}4 \times 10^{-4}}{n}$$

where $n = 1$ $\quad r = 8{\cdot}48 \times 10^{-4}$

" $n = 2$ $\quad r = 4{\cdot}24 \times 10^{-4}$

" $n = 4$ $\quad r = 2{\cdot}12 \times 10^{-4}$

" $n = 8$ $\quad r = 1{\cdot}06 \times 10^{-4}$

" $n = 16$ $\quad r = 53 \times 10^{-6}$

Octopolar Dynamo.

Calculations for winding field magnets.

Problem. Having given the number of ampere-turns necessary to produce a certain magnetisation, and the weight of wire available on each coil, to find the size of wire needed and the heat energy expended in it.

Let c be the current in each magnet coil

" t " " number of turns on each coil.

" v " " mean normal voltage required from the machine

" R " " resistance when hot of each coil

" n " " number of coils in series

" d " " mean diameter of one turn in feet.

" r " " resistance per foot of the wire required.

" N " " number of ampere-turns

Then

$$N = ct$$

$$c = \frac{v}{nR}$$

$$R = \pi d t r$$

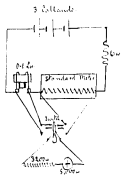
$$\therefore N = \frac{vt}{n \pi d t r} = \frac{v}{n \pi d r} \quad \therefore r = v / N n \pi d$$

In this particular case $N = 7300$ $\pi d = 2{\cdot}1$

From these data we obtain the following table.

Arrangement of coils	Res per foot formula	Resist. in Ω	Bare wire diameter in inches	Current per coil	Total current	Highest volts required	Total Watts expended	Watts expended in each coil	Total Res of each branch	Res of all finally
16 in series	$5{\cdot}3 \times 10^{-4}$	0·165" #8	0·138	59	59	130	7650	480	2·25	2·21
2 series of 8	$1{\cdot}06 \times 10^{-3}$	0·095" #12	0·26	12·7	24·2		3150	19·4	19·8	5·4
4 series of 4	$2{\cdot}12 \times 10^{-3}$	0·072 #15	3·51	9·3	37·2		4840	303	14·0	3·51
8 series of 2	$4{\cdot}24 \times 10^{-3}$	0·049 #18	17·8	3·7	29·0		3770	236	35·6	4·45
16 series of 1	$8{\cdot}48 \times 10^{-3}$	0·035 #20	68·1	1·9	30·5		3970	250	68·1	4·25

It will therefore be best to add 10 lbs of wire to each magnet coil, of same wire, making 16 lbs in all of #15 increasing the length from 7·6 to perhaps 11·6 all told. making the refill 1·85".



Calculation of Probable Error

No. of obs.	Obs.	Mean	Residual v	v^2	Σv^2	$\sqrt{\frac{\Sigma v^2}{n(n-1)}}$	0·6745 $\sqrt{\frac{\Sigma v^2}{n(n-1)}}$	Adjusted value of Meter #1
1	0·99370	0·99352	+0·00082	6.72×10^{-6}				
2	0·99488		+0·00086	7.38×10^{-6}			0·2754 × 0·00106 = 0·000292	0·99445 ± 0·000029 @ 21°C
3	0·99457		+0·00065	4.25×10^{-6}	112.05×10^{-6} 1.1205×10^{-4}	1.06×10^{-3} 0·00106		
1	0·99652	0·99712	+0·00060	36.0×10^{-6}				
2	0·99900		−0·00188	353·4				
3	0·99678		+0·00034	11·6				
4	0·99752		−0·00040	16·0				
5	0·99801		−0·00099	79·2			0·0795 × 0·00267 = 0·00021	0·09980 ± 0·000021 @ 21°C
6	0·99702		+0·00010	1·0				
7	0·99652		+0·00060	36·0				
8	0·99702		+0·00010	1·0				
9	0·99579		+0·00133	176·9	711.1×10^{-6} 7.111×10^{-6}	2.67×10^{-3}		

Meter Experiment contd :-

November 15th Thursday.

Measured the resistance of the shunts and spools of the two new standard Meters made at the laboratory, by comparison with the 0·1 standard lent by Mr Bergmann.

Found up connections shewn so that the switch could change the PD easily without much disturbance of the spot under a lens.

Meter Number 1

No. of obs.	Deflection on Meter	Deflection on Standard Meter	Temp. of Standard 0·1	True Res. of Std. at temp.	Differential Difference	Ratio	True value of Meter	Temp. of Meter	Probable Temp. at which Meter becomes correct
1	405·8	403·0			2·8	0·99310	0·9937		
2	405·8	403·4	20·2°C	0·10006	2·4	0·99408	0·9947	21·5°C.	48°C.
3	405·6	403·4			2·2	0·99457	0·9952		
Mean	405·73	403·27			2·46	0·99392	0·99452		

Meter Number 2

No. of obs.	Deflection on Meter	Deflection on Standard 0·1	Difference	Ratio	Temp. Std. 0·1	True Res. of Std. at temp.	True value of Meter	Temp. of Meter	Probable Temp. at which Meter becomes correct
1a	401·5	402·9	1·4	0·99652					
1	401·4	401·8	0·4	0·99900					
2	402·0	403·3	1·3	0·99678					
3	402·5	403·5	1·0	0·99752					
4	402·2	403·0	0·8	0·99801	22·0°C.	0·10009			
5	402·0	403·2	1·2	0·99702					
6	402·0	403·4	1·4	0·99652					
7	402·0	403·2	1·2	0·99702					
8	401·8	403·5	1·7	0·99579					
Mean	401·93	403·09	1·16	0·99712			0·99802	21°C.	31°C.

Experimental Standard Meter

No. of obs.	Deflection on meter	Deflection on Std. 0·1	Difference	Ratio	Temp. Std. 0·1	True Res. of Std. at temp.	True value of Meter	Temp. of Meter	Probable Temp. at which Meter comes correct
1	397·1	405·0	7·9	0·98049					
2	397·5	404·5	7·0	0·98269	22·0°	0·10009			
3	397·5	404·6	7·1	0·98245					
Mean	397·37	404·70	7·33	0·98188			0·98276	20°C	59°C.

Meter Experiments contd.

November 15th Thursday

Checked the above measurements by bridge.
Used 4 stout wires of equal length as leads two for the meter and two for the standard tenth.
The resistance of all these four together was observed to be 0·01053 or 0·00527ω per pair.

Meter No. 1.

No. of Obs.	Bridge	Calculated Balance on Std.	Calculated Balance on Meter	Leads.	Corrected for leads O-Std.	Corrected for leads Meter.	Ratio	Value of O-Std at temp	Calculated value of Meter
1	1000/10 24·1°C	0·10505		0·00527	0·09978	0·09926	0·9948		
2			0·10453					0·10006	0·9957ω @ 22°C.
3		0·10480			0·09953	0·09910	0·9957		
4			0·10437						
Mean		0·10493	0·10445	0·00527	0·09967	0·09918	0·9951	0·9957	
1	1000/10 24·1°C	0·10505		0·00527	0·09978	0·09935	0·9957	0·10006	0·9963ω @ 22°C.
2			0·10462						

Resistance of spool and left hand wire to spool.

Meter	Bridge	Balance	Balance Corrected	Mean.	Leads.	Cor. for Leads	Cor. for TB to 15°C.	Temp. spools	
1	1000/10 24·1°C	97·91	97·88	97·90	0·02	97·88	98·03	22°C.	
2		97·91	97·89	97·90	0·02	97·88	98·03		

Calculation of Probable Error.

Meter	Obs. ratio cor. for leads	Mean.	Residual v	v^2	Σv^2	$\sqrt{\Sigma v^2}$	$0.6745\sqrt{\frac{\Sigma v^2}{n(n-1)}}$	ε	Adjusted value
1	0·9948	0·99525	0·00485	20.25×10^{-6}	40.5×10^{-6}	6.36×10^{-6}	0.4769×0.00062	±0·0003	0·9957 ± 0·00003
2	0·9957		0·00445	20.25×10^{-6}					

Measured the resistance of 25th bottles Nos. VI and VII which have been left untouched since the 10th inst.

Bottle No.	Plate Nos.	Bridge	Current thro bottle	Res. in ect.	Res. dead	Leads.	Res. of bottle	Temp. of bottle.	Days standing
VI	1+2	1000/10	1 milliampère	7000ω	2·22	0·26	1·96	20°C.	15
VII	3+4				32·00	~~24·74~~	31·74		

Plates Nos. 1 + 2 unvarnished, but amalgamated, still retain their bright lustre though covered by bubbles of gas.

Meter Experiments contd:

November 16th Friday.

Measured the resistances of the 25 lt meter bottles observed yesterday and on the 10th inst.

No. of Bottle	Date of bottling by	Days at rest	Plates	Solution	Pages of Rough Book	Results observed 16.11.88	Leads	Wt. of bottle	Bridge, Remarks &c.	Temp. Bottle
VI	31.10.88	16	plain amal.	varied b/50°	11, 20, 29	2.4	0.26	1.85	temp/o	22.1°C
VII	- - -	16	" "	not heated	11	39.7		38.42	7000 = in circ	
VIII	- - -	16	corrodes amal.	varied b/70°		16.2		15.92		
IX	- - -	16	do. do.	not heated		30.2		29.92	1 micromp.	
X	3.11.88	13	plain amal.	varied b/50°		23.3		23.04	Rhea. bottle	
XI	7.11.88	9	corrs. amal.	not heated		53.0		52.74	for few moments	
XII	8.11.88	8	corrs. amal.	varied b/60°		100.		99.74	only	
XIII	9.11.88	7	plain amal.	varied b/60°		6.3.		6.04	No falls in res. observed with any bottle	

To ascertain whether a clean zinc surface suffered any corrosion at the boundary surface between pure zinc sulphate solution and air, took a Leclanché zinc rod and after amalgamating it passed it through a cork into a test-tube half filled with ordinary meter solution and set it aside labelled no. XIV

November 17th Saturday

To ascertain whether a clean copper surface suffered any chemical change beneath when immersed in meter solution, took a test-tube of clean meter solution and immersed in it a strip of copper foil cleaned by nitric acid. Labelled XV

To ascertain once more whether any advantage as regards weight of oxidisation resulted with zinc alloyed with a small percentage of mercury, took 6 new plates of the dimensions and properties recorded on page 3, after weighing left them in meter solution, contained in an evaporating dish.

No. of plate	% of Hg alloyed	Condition of surface	Weight in air by Sartorius 11.11.88	Weight in water	Discrepancy	Adjusted Sartorius Weight	Adjusted Bridge Weight	Sum as check	Labelled	
O_5	0	plain	94.6747	189.6070	+ 0.0005	94.6769	189.6068	189.6069		
O_7	0	"	94.9298			94.9300				
O_1	0	amalgamated	87.2607	176.6378	+ 0.0006	87.2609	176.6376	176.6376	XVI	
O_9	0	do	89.3765			89.3767				
I_1	1	plain	95.1988	184.1062	+ 0.0005	95.1990	184.1060	181.1061		
I_7	1	do	88.9069			88.9071				

$\log 1.00388 = 0.0016828 \times 25 = 0.042070 = 1.1017$

$0.1017\ R = 0.87$

$R = 8.55$

$\log 1.005 = 0.0021661 \times 25 = 0.054153 = 1.1328$

$0.1328\ R = 0.87$

$R = 0.55$

Calculation of the best method of compensating the temp. error in the bottle resistance. (31)

Let C = the service current

" c = " current passing through the bottle

" b = " resistance of the bottle

" r = " " " " spool.

" s = " " " " shunt.

Then $c = \dfrac{Cs}{b+r+s}$

and $\dfrac{dc}{db} = \dfrac{-Cs}{(b+r+s)^2}$

From the curves representing the sp. res. of 2w50 solution, it would seem that the spec. res. of solution having a density of 1.0514 would be 32w @ 50° C.

38w @ 40° C.
45w @ 30° C.
50w @ 20° C.
70w @ 5° C.

Assuming the res. of a 25lt. bottle to be 1.75w @ 20° C.
its res. would be $\dfrac{1.75 \times 70}{50}$ = 2.45w @ 5° C.

and $\dfrac{1.75 \times 45}{50}$ = 1.58w @ 30° C

The res. of the bottle changes from 1.58 to 2.45 or 0.87w between 30° and 5° C. and the problem is to find the resistance of copper whose coeff. of temp. is 1.00388 or of iron whose coeff. is 1.005. will bring about an equal change between these temperatures. We have therefore $R(1.00388)^{25} - R = 0.87$ and $R(1.005)^{25} - R = 0.87$

whence $R = 8.55$ @ 5° C and $R = 6.55$ @ 20° C

$= 9.04$ @ 20° C

9.38 @ 30° C by Lobb's c.s.

If through oxidation, the resistance of a bottle increases by y show the percentage of reduction in current passing through the bottle will be $\dfrac{100y}{b+r+s+y}$

When $b+r+s = 10$ the effect of 1w is to reduce the current 9.1%

" 2w " " " " 16.7%

" 3w " " " " 23. %

" 4w " " " " 28 %

" 5w " " " " 33.3%

If the resistance of the bottle were doubled by diminishing the area of the plate, the spool resistance would also be doubled and with $b+r+s = 20$

the effect of 1w extra in the bottle would reduce the current 4.5%

" " " 2w 8.4 "

3w 11.5 "

4w 14.0 "

5w 16.7 "

It seems probable that the oxide error would be increased in like proportion, since if ρ be the film res. per sq. cm. then the res. of the present plate film is $\dfrac{\rho}{A}$ A being the effective plate area. When A is halved this becomes $\dfrac{2\rho}{A}$

Meter Experiments contd —

November 19th Sunday.

Before taking down the bottles that have been in operation on the meter heat since the 5th inst. took the resistance of each after

No of bottle	Name of meter	Temp of meter	Bridge	Res. in ohms	Current	Res.	Leads.	Res. bottle	Calculated % Difference	
1-2	Standard	15.6°	1000/10 17.19	7000	1 microamp	3.70	0.26	3.44	1.7%	
3-4	#2 bottle	20.0°				3.20		2.94	12 %	
5-6	- -	-				2.70		2.44	76%	
7-9	#1 cold	7°								
10-11	- -					4.50		4.24	17%	
						3.75		3.49	12.4%	

Took down bottles dried and weighed plates as follows —

No. of bottle	Weight empty 17.11.88	Joint weight	Sum of weights	Discrepancy	Adjusted single value	Adjusted joint value	Adjusted single value 19.11.88	Loss	Gain	Calculated Standard loss	% Error
1	86.4905	174.4434	174.4434	+ 0.0010	86.4908	174.4452	87.1900	0.7072	0.7072	0.7196	
2	87.9539				87.9542		87.2381	~~0.71~~	0.7161		
3	88.3127	170.0195	170.0188	+ 0.0007	88.3129	170.0193	87.6248		0.6881		
4	81.7061				81.7063		82.3766	0.6703			4.38
5	89.8530	176.4250	176.4250	+ 0.0006	89.8530	176.4254	89.1537		0.6995		
6	86.5720				86.5722		87.2421	0.6899			4.14
8	85.9396	173.7141	173.7134	+ 0.0007	85.9398	173.7139	86.5614	0.6216			
9	87.7739				87.7740		87.1439		0.6301		13.62
10	86.8855	173.9925	173.9902	- 0.0007	86.8853	173.9937	86.2296		0.6557		
11	87.1057				87.1035		87.7508	0.6423			10.75

No of exp.	No of Meter	Mean temp	Loss.	Mean Cell loss	Diff Temp	Ratio Cell loss / Meter loss	% Error per °C.	Gain by oxidation	Standard values 20.10.88 Ratio Cell loss / Meter loss	% Error per °C	Joint Meter 20.10.88 Gain by oxidation
1-2	Std.	18°	0.7072	0.7196				0.0091			0.0296
3-4	#2	24.5°	0.6703	0.6802	16.5°	1.0581	0.42	0.0178	1.073	0.19%	0.04187
5-6			0.6899					0.0095			0.044422
7-9	#1	8°	0.6216	0.6320		1.139		0.0085	1.109		0.04112
10-11			0.6423					0.0138			0.05742
							Mean	0.0116			0.04443

% of oxidation reduced. 74%

All the plates in the heat just completed were varnished on back and edge, thus reducing the oxidation weight excess to one fourth its former amount, but in the same number of days exposure, but not altering the meter error due to extra resistance, except in so far as the resistance of the bottles may have been increased by reduced surface.

Meter Experiments contd:

November 19th Monday

Set up a new meter comparison test between the three standard meters and the two commercial meters. Also bottles in the three standard meters contained solution that had been raised to 90°C before the immersion of the zincs. One bottle in each of the commercial meters was similarly heated, the other bottle being set up at Normal temperature in the usual way.

No. of Bottle	Condition	Weight singly	Sum	Observed weight of pair	Difference	Adjusted single weights	Adjusted pair weights	Sum as check	Bottle Entitled No.	Meter
1	Immersed	85·6352	175·4699	175·4702	+0·0003	85·6353	175·4701	175·4701	XVII	Standard #1
2	except	89·8347				89·8348				
3	at base	88·9011	177·8263	177·8270	+0·0007	88·9013	177·8268	177·8267	XVIII	Standard #2
4	of rods	88·9252				88·9254				
5	and	81·1423	169·1865	169·1870	+0·0005	81·1425	169·1868	169·1869	XIX	Exp. Standard
6	on rods	88·0442				88·0444				
7	thereafter,	81·8794	172·0906	172·0912	+0·0006	81·8796	172·0910	172·0910	XX	Meter #2 A
8	Amalgamated	90·2112				90·2114				
9	3 times	89·0542	178·4463	178·4460	−0·0003	89·0541	178·4461	178·4461	XXI	Meter #2 A
10		89·3928				89·3920				
11		91·6106	180·2523	180·2525	+0·0002	91·6107	180·2524	180·2525	XXII	Meter #2 B
12		88·6417				88·6418				
13		87·6481	169·2161	169·2165	+0·0004	87·6482	169·2164	169·2163	XXIII	Meter #1 B
14		81·5680				81·5681				

Bottles XVII to XXI inclusive were heated XXII and XXIII left unheated.
Took the resistance of these and other bottles as follows:—

Bottle No.	Varnish	Solution	Date	Page of work	Bridge	Resistance	Current	Res. read corrected for load	Temp. of air in room	Remarks
XVI	on rods only	heated	31.10.88	11, 22, 29, 30	1000/10	7000	1 microamp.	1·82	26·4°C	
XVII	- - -	not heated	- - -	- - - -	-			30·0		
XIV	back & rims	not heated	9.11.88	20				8·19		
XV	- -	not heated	- - -	-				30·0		
XVII	on rods only	heated	19.11.88					1·52		Still warm
XVIII	- - -	-	-					1·44		" "
XIX	- - -	-	-					1·51		- -
XX	- - -	-	-					1·84		- -
XXI	- - -	-	-					1·46		- -
XXII	- - -	not heated	-					1·16		
XXIII	- - -	not heated	-					1·49		

Resistance of Meter spools before closing circuit

No. of Spool	Meter	Spool	Res. read	Leads	Cold for load	Meter	Spool	Res. read	Leads	Cold for load
1	Edison #1a	Left hand	8·50	0·27	8·23	Edison #2 warm	A	8·53	0·27	8·26
2		#2	8·45		8·18		B	8·52		8·25
3		#3	8·44		8·17	Edison #1 cool	A	8·30		8·03
4		Right hand	7·59		7·32		B	8·37		8·10
5	Exp. Standard		98·45		98·18					

Current of 3·8 amperes put on at 16 o'clock.

Experiments on the antiseptic power of Gasolene Rhigolene & Benzic Potash.
by Dr. Dockins

To ascertain whether the admixture of gasolene to an organic solution will prevent or retard bacterial development. 5 test tubes were taken on the 27th October and filled with fresh undecomposed urine mixed with gasolene in the following proportion.

#1	5% Gasolene
#2	10% "
#3	20% "
#4	50% "
#5	Plain urine

These were set aside and occasionally shaken.

#5 showed plenty of live bacteria after 24 hours on the 1st Nov.
#1 - very few motionless - - - - - - - .
#1 - distinct moving - - 48 - 2nd .
#2 - very few motionless - - 48 - - - .
#5 - abundant live - - 48 - decomposing.
#1 2 3 - distinct increasing number of - - 120 - 5th Nov
but no change or decomposition visible in #3 and 4
#3 - first appearance of bacteria after 144 - 6th Nov
#4 first showed a few bacteria with the highest power on the 9th Nov after 216 hours (9 days) and from day to day subsequently slow increase in the number was visible, with corresponding cloudiness in the solution.

Took a small quantity of finely chopped hay and left it for 24 hours soaking in a testtube of gasolene. Then I emptied gasolene from testtube and refilled it with distilled water, on the 1st November. A slight film of gasolene about 1/8" deep remained on the surface of the water. This was set aside to see if microbes would develop.

No bacteria were visible after 96 hours on the 5th
& few bacteria were visible after 29 days.

It was ascertained that dead bacteria do stain in aniline dyes but not so readily as when living

To ascertain the retarding influence of gasolene vapor placed some boiled urine subsequently exposed to air in a testtube within a florence flask at the bottom of which was found some gasolene. The cork of the flask was sealed. This was set aside on the 2nd November.
Up to the 20th no clouding of the urine has been visible

This experiment was repeated on the 8th with fresh urine in a test tube similarly suspended.
Up to the 20th the urine remains perfectly clear.
A similar testtube left unprotected, became cloudy and swarmed with bacteria next day.

On the 3rd November five drops of decomposing urine were added to a test tube containing some fresh urine, to the whole was then added an equal bulk of gasolene. On the 5th no perceptible microbe increase was visible. Up to the 10th very slight increase was visible.

Meter Experiments contd:-

November 20th Tuesday

Measured the resistances of the various bottles as follows:-

No. of bottle	Date & time of obs	Date of setting up	Days since set up	Solution	Surfaces	Res: obs (leads deducted)	Temp:	Current	
VI	8.40. 20.11.88	31.10.88	20	heated	plain varnished	2.62	18.4°C	1 m: amp	
VII		31.10.88	20	not heated	- -	46.0			
XIV		9.11.88	11	- -	varnished	12.84			
XV		9.11.88	11	- -	-	51.0			
XVII		19.11.88	1	heated	plain varnish	2.23			
XVIII		19.11.88	1	-	- -	2.83			
XX		19.11.88	1	-	- -	2.23			
XXII		19.11.88	1	not heated	- -	2.23			
XXIV		19.11.88	1	not heated	- -	3.64			
XXV		19.11.88	1	heated	- -	4.84			
XXVI		19.11.88	1	-	- -	5.04			
XXVII		19.11.88	1	-	- -	11.44.			

Nos. XVII to XXI inclusive were heated by interrupting the meter current temporarily and measuring the resistance quickly with 1 m: amp.

The bottles XXIV, XXV, XXVI, and XXVII were made up on the evening of the 19th Nov: as follows:-

XXIV a 12lt bottle plates already used, cleaned and amalgamated, set up without heating in the usual way

XXV a similar 12 lt bottle made up in usual way except that temp: was brought up in sand-bath to 92°c. and when cool the plates were inserted.

XXVII A similar 12 lt bottle heated to 92°c but with the zincs immersed during the heating. Bubbles formed on these zincs during the process of heating.

XXVI A similar 12 lt bottle heated to 92°c, and with the zincs separately ~~heated in air to about 100°c~~ immersion in the hot solution after it removal from the sandbath.

Two more bottles were made up on the 20th November as follows

XXVIII a 25 lt bottle raised to 90°c with plates unvarnished but amalgamated raised separately in air to 90°c and immersed in the bottle solution on removal of bottle from sand bath.

XXIX a 25 lt bottle raised to 90°c with unvarnished amalgamated plates immersed during the process.

XXX a 12 lt bottle set up to test varnish only. The plates were varnished with Fessenden's insulating material dissolved in $CHCl_3$ the resistance at 20° was observed to be 3.37. It was then raised to boiling point in a sandbath and after cooling (the temperature was allowed to fall slowly) the resistance was:- 4.45.

Gasoline Experiments cont.

Two earthworms were enclosed in a testtube of distilled water after being carefully washed and a layer about 1" deep of gasoline poured on top. The cork was then sealed on the 10th November. After 48 hours incipient decomposition was visible. On the 13th they floated to the bounding surface of the liquids having distinctly decomposed. Microscopic examination then revealed bacteria in the water in large numbers.

Up to 11th Dec: no clouding visible in the urines contained in the florence flasks alluded to on page 340. Both remain quite clear.

On the 12th Nov. a small quantity of fresh earth was introduced into a testtube filled with gasoline above it. After this remained for 24 hours, the gasoline was poured off and replaced by fresh water from the tap.
On the 20th Nov. this water on examination showed a few bacteria (obviously greatly retarded by the presence of the gasoline.
On the 11th Dec. there were present numerous bacteria in sporadic condition.

The following experiment was commenced with caustic potash on the 9th November. Added certain definite weight of pure caustic potash to test tubes of fresh urine.

No 1. contained 6½% KHO.
" 2 " 12½ " " .
" 3 " 25 " " .
" 4 " 0 % " plain urine.

} These were sealed + set aside.

On the 12th bacteria were found in specimens of #4.
none in nos 1, 2, or 3.
On the 14th numerous bacteria in #4, none in the others.
On the 11th Dec: " " " " " " "
Daily examination of specimens from these tubes which had to be exposed to the air on each occasion for that purpose shews that the dissolved KHO. has imparted immunity from bacterial life to the urine up to date.

The following experiment was commenced with sesquichloride of iron Fe_2Cl_6 in solution on the 23rd November. Added ~~[illegible]~~ definite weight of the red crystal Fe_2Cl_6 to freshly voided urine as follows.

No 1. contained 1% Fe_2Cl_6
2 " 2% " "
3 " 4% " "
4 " 8% " "
5 " 16% " "

} These were sealed + set aside

On the 23rd, tubes were found to be all clear, no bacteria visible on examination.
On the 24th, same result.
On the 11th December examination showed no bacteria and certainly no live bacteria in the 1% solution. All clear and no change in the odor. It is certain therefore that up to date the amount of 1% of this salt has prevented decomposition in urine sealed but daily exposed for a few moments to air.
Up to the 31st December only no 1. was found to contain bacteria.

Meter Experiments contd: November 21st Wednesday.

The resistance of the various bottles was measured at 8.30 as follows

The 12 bottles	Date of making up	Temp at Nett	Plates Size	Solution	Plates	Res. when first heated	Res. now observed.	Varnish	Temp.	Current
XI	31.10.88	21	25	heated to 90°	immersed at 8°	8.25° 9.11.88	2.7	rude	16.2°C	1 ma.
XII	31.10.88	21	25	not heated	—	Temp. 9.11.88	50.	"	-	.
XV	9.11.88	12	25	not heated	.	8.20 24° 19.11.88	17.	back crime	-	.
XI	9.11.88	12	25	not heated	-	30.00 24° 19.11.88	56.	- .	-	.
XVII	19.11.88	2	25	heated to 92°	immersed at 90°	2.23 @ 18° 20.11.88	2.0	rude	std. meter #1	.
XVIII	19.11.88	2	25	- . .	- -	2.30 @ 18° 20.11.88	2.25	-	std. meter #2	-
XIX	19.11.88	2	25	- - -	- - -	2.23 @ 18° 20.11.88	2.0	-	Meter #2	-
XXI	19.11.88	2	25	- - -	- - -	2nd taken	2.70	-	Meter #1	.
XXII	19.11.88	2	25	not heated	———	2.23 @ 18° 20.11.88	2.73	-	Meter # 2	-
XXIII	19.11.88	2	25	- -	———	not taken	2.45	.	Meter # 1	-
XXIV	20.11.88	1	12	- -	-	3.6 @ 18° 20.11.88	3.55	-	16.2°C.	-
XXV	20.11.88	1	12	heated to 98	immersed cleaned	4.10 @ 18° . . .	4.65	-	- .	.
XXVI	20.11.88	1	12	- . 92°	immersed hot	5.00 @ 18° . .	4.60	-	- .	.
XXVII	20.11.88	1	12	- . 90°	heated in sol.	11.44 @ 18° . .	11.85	-	- .	.
XXVIII	20.11.88	1	25	- - -	heated in air	——	7.45	-	- .	—
XXIX	20.11.88	1	25	- - -	heated in sol.	——	2.85	-	- .	.
XXX	20.11.88	1	12	varnish	not - - .	3.37 @ 18° . .	4.45	-	- .	.

Took one of the 12lt bottles made up on the 5th October which has been set aside inactively since that date (47 days) its resistance at 17°C was observed to be 67.0 w. The bottle was then heated as it stood on a sandbath to boiling point. The res: when hot perhaps 90° was still 59 w. but after cooling fell to 55 w.

November 22nd Thursday

Made up 4 25 lt bottles @ follows

XXXI was set up with ordinary city water from the tap, & heated to 90°C. with the amalgamated zincs in it.

XXXII was similarly set up but not heated.

XXXIII was similarly set up but the zincs were separately heated in $ZnSO_4$ solution to 100°C and then immersed in the bottle while still hot.

XXXIV was set up with Chapman c.p. solution made from distilled water in the ordinary way and not heated

XXXV - - - with c.p. $ZnSO_4$ solution and heated to 90°C.

Taking any three equations for separate solution such as

(1) $a + 2.4b + 5.76c = 2.4474$

(2) $a + 4.13b + 16.81c = 2.485$

(3) $a + 15.8b + 249.6c = 1.000$

by (1) $a = -2.4b - 5.76c + 2.4474$

(2) $-2.4b - 5.76c + 2.4474 + 4.13b + 16.81c = 2.485$
$+ 1.7b + 11.05c = -1.989$

(3) $-2.4b - 5.76c + 2.4474 + 15.8b + 249.6c = 1.000$
$+ 13.4b + 243.88c = -3.4474$

(2) $b = \frac{-11.05c}{1.7} - \frac{1.989}{1.7}$
$= -6.5c - 1.17$

(3) $-13.4 \times 6.5c - 13.4 \times 1.17 + 243.88c = -3.4474$
$-87.1c - 15.68 + 243.88c = -3.4474$
$156.78c = 12.206$
$c = 0.0779$

$b = -6.5 \times 0.0779 - 1.17$
$= -0.506 - 1.17$
$= -1.676$

$a = 2.485 + 4.13 \times 1.676 - 16.81 \times 0.0779$
$= 2.485 + 6.922 - 1.309$
$= 8.098$

$8.098 + 2.4 \times -1.676 + 5.76 \times 0.0779 =$
$= 4.022 + 0.449 = 4.475$

No. of equat.	Residual v	Residual squared v^2	Σv^2	$\frac{0.6745}{\sqrt{n-1}}$	$\sqrt{\Sigma v^2}$	$0.6745\sqrt{\frac{\Sigma v^2}{n-1}}$	$0.6745\sqrt{\frac{\Sigma v^2}{n(n-1)}}$	$0.6745\sqrt{\frac{\Sigma v^2}{n(n-3)}}$	Σv
1	−0.69	0.4761							
2	+0.50	0.2500							
3	+0.88	0.7744							+ 1.81
4	+0.02	0.0004							
5	−0.36	0.1296	2.2191	0.2894	1.49	0.584	0.4278	0.192	
6	−0.59	0.3481							
7	−0.17	0.0289							
8	+0.46	0.2116							− 1.83
									3.64 ÷ 8 = 0.4468

The probable error of any observed sp. res. varying between 13 and 34 with a mean of 23.5 say is 0.581 or 2.5%

and the equation for the parabola is $37.99 - 0.9313t + 0.0088t^2 \pm 0.190$

Resistances of $ZnSO_4$ solution and temp. coeff. continued. from p. 23.

Taking the equations on p. 23 with the values $a = 3.8114$ $b = -0.219$ $c = 0.00287$ we have.

0.511	$a + 20.7b + 428.5c$	$= 0.924$	(1)	$3.8114 - 4.533 + 1.230 - 0.924$	$= -0.413$
0.814	$a + 17.9b + 320.4c$	$= 1.003$	(2)	$3.8114 - 3.920 + 0.920 - 1.003$	$= -0.189$
1.132	$a + 14.8b + 219.5c$	$= 1.073$	(3)	$3.8114 - 3.241 + 0.629 - 1.073$	$= +0.129$
1.645	$a + 11.7b + 136.9c$	$= 1.218$	(4)	$3.8114 - 2.562 + 0.393 - 1.218$	$= +0.427$
2.263	$a + 7.9b + 62.4c$	$= 1.581$	(5)	$3.8114 - 1.730 + 0.179 - 1.581$	$= +0.722$
2.984	$a + 4.1b + 16.8c$	$= 2.485$	(6)	$3.8114 - 0.898 + 0.028 - 2.485$	$= +0.479$
3.305	$a + 2.4b + 5.8c$	$= 4.4474$	(7)	$3.8114 - 0.526 + 0.017 - 4.4474$	$= -1.169$
1.070	$a + 15.8b + 249.6c$	$= 1.000$	(8)	$3.8114 - 3.460 + 0.716 - 1.000$	$= +0.070$

No. of equat.	Residual v	v^2	Σv^2	$\frac{0.6745}{\sqrt{n-1}}$	$\sqrt{\Sigma v^2}$	$0.6745\sqrt{\frac{\Sigma v^2}{n-1}}$	$0.6745\sqrt{\frac{\Sigma v^2}{n(n-1)}}$			
1	−0.413	0.1706								
2	−0.189	0.0357								
3	+0.129	0.0166								
4	+0.427	0.1823	2.5297	0.2549	1.59	0.2549 × 0.2249 = 0.4053	0.0901 × 1.59 = 0.1433			
5	+0.722	0.5213								
6	+0.479	0.2294								
7	−1.169	1.3669								
8	+0.070	0.0049								
	3.598									

The table shows that the curve is not a parabola.

The following table presents Euring and MacGregor's results @ 10°C

No.	Density	% of Anhydrous $ZnSO_4$	sp. res. ρ_t	sp. res. ρ_{18}	calculated by formula	Ratio k that of 1:185 18	No.	Density	% of Anhydrous $ZnSO_4$	sp. res. ρ_t	sp. res. ρ_{18}	calculated by formula	Ratio k that of 1:185 18
1	1.0140	1.4	182.9			5.70	11	1.2709	22.6	32.2	28.5	27.9	0.888
2	1.0187	1.8	140.5			4.38	12	1.2891	24.0	29.9	28.3	27.9	0.882
3	1.0278	2.7	110	111.1	12.7	3.46	13	1.2895	24.0	32.2	28.5	27.9	0.888
4	1.0540	5.0	63.1	63.8	65.2	1.99	14	1.2987	24.3	32.2	28.7	27.9	0.894
5	1.0760	7.0	50.1	50.8	48.8	1.58	15	1.3288	26.5	29.9	29.2	28.1	0.910
6	1.1019	9.5	40.6	42.1	40.0	1.31	16	1.3530	28.1	34.7	31.0	28.8	0.966
7	1.1582	14.2	33.3	33.7	32.0	1.05	17	1.4053	31.36	34.7	32.0	33.5	1.000
8	1.1845	16.2	31.5	32.1	29.3	1.00	18	1.4174	32.0	33.0	33.4		1.040
9	1.2186	18.6	30.0	30.3	28.1	0.944	19	1.4220	33.0	33.3	33.7		1.050
10	1.2562	21.5	29.3	29.2	28.1	0.910	20						

Taking the equations from page 2 and the values $a = 37.99$ $b = -0.9313$ $c = +0.0088$

$a + 5b + 25c$	$= 34.26$	$37.99 - 4.66\frac{1}{2} + 0.22$	$= 33.55$	-0.69
$a + 12.5b + 156.3c$	$= 27.23$	$37.99 - 11.64 + 1.38$	$= 27.73$	$+0.50$
$a + 16.1b + 259.2c$	$= 24.39$	$37.99 - 15.00 + 2.28$	$= 25.27$	$+0.88$
$a + 24.4b + 697c$	$= 19.51$	$37.99 - 24.89 + 6.13$	$= 19.53$	$+0.02$
$a + 32.1b + 1030.4c$	$= 17.52$	$37.99 - 29.90 + 9.07$	$= 17.16$	-0.36
$a + 39.2b + 1536.6c$	$= 15.61$	$37.99 - 36.51 + 13.53$	$= 15.02$	-0.59
$a + 45.5b + 2070.3c$	$= 14.00$	$37.99 - 42.38 + 18.22$	$= 13.83$	-0.17
$a + 52.2b + 2724.8c$	$= 12.88$	$37.99 - 48.62 + 23.97$	$= 13.34$	$+0.46$

Rule for determining the specific resistance of any solution density of zinc sulphate — Find the density at 20°C with this from the table or curve find the coefficient k. The spec. res. will then be at the temp of t°C.

$k\,(37.99 - 0.9313t + 0.0088t^2)$

Meter Experiment contd
November 22nd Thursday

Took resistance of bottles as follows —

No. of bottle	Date of setting up	Days elapsed	Size of Plates	Solution	varnish	Plates	Res. when first tested	Res. now observed	Temp.	Current
XVI	31.10	22	25"	heated to 81°	roots only	immersed at 80°	2.5 on 23° 9.11.88	1.99	21.2°C	1 mono
XVII	31.10.	22	25"	not heated	- - -	—	7.1 on 23° . . .	39.	-	-
XIV	9.11	13	25"	- -	backs varnish	—	5.2 on 23° 19.11.88	16.74	-	-
XV	9.11	13	25"	- -	backs varnish	—	4.00 23° 19.11.88	46.	-	-
XVIII	19.11	3	25"	heated to 90°	roots only	immersed at 90°	2.23 on 18° 20.11.88	1.74	Old meter #1	-
XVIII	19.11	3	25"	- - -	- -	- - -	2.23 on 18° 20.11.88	1.94	Old Meter #2	-
XX	19.11	3	25"	- - -	- -	- - -	2.23 on 18° 20.11.88	1.84	Meter #2	-
XXI	19.11	3	25"	- - -	- -	- - -	2.23 on 18° 20.11.88	2.44	Meter #1	-
XXV	19.11	3	25"	not heated	- -	—	2.23 on 18° 20.11.88	2.49	Meter #2	-
XXIII	19.11	3	25"	- -	- -	—	2.25 on 18° 20.11.88	2.44	Meter #1	-
XXII	20.11	2	12	- -	- -	—	3.64 on 18° 21.11.88	2.99	24.2°C	-
XXV	20.11	2	12	heated to 90°	- -	immersed when hot	4.34 on 18° 21.11.88	3.84	-	-
XXVI	20.11	2	12	- -	- -	immersed hot	5.04 on 18° 21.11.88	3.99	-	-
XXVII	20.11	2	12	- - -	- -	heated in sol.	11.44 on 18° 21.11.88	7.44	-	-
XXVIII	20.11	2	25"	- - -	- -	heated in air.	7.45 on 18° 21.11.88	4.44	-	-
XXIX	20.11	2	25"	- - -	- -	heated in sol.	2.55 on 18° 21.11.88	1.94	-	-
XXX	20.11	2	12	varnish hot	backs varnish	- - -	4.45 on 18° 21.11.88	3.24	-	-

November 23rd Friday

No XXXVI was made with zincs amalgamated for the third time but not amalgamated, distilled mercury and chemical room solution heated with the zincs in place to 90°C. The zinc electrodes were coated with collodion varnish.

No XXXVII was made as above but without heating the solution zincs which were inserted in the solution after heating and when still hot

No. XXXVIII plain new zincs cleaned not filed not amalgamated in chemical room solution not heated

No XXXIX same as last (XXXVIII) but solution heated with zincs in place to 90°C.

No XL Amalgamated unvarnished zincs same treatment as XXXVII except that solution heated more rapidly.

XL I
XL II
XL III } varnish test.

a quantity of mercury was distilled for amalgamation

November 24th Friday

Found the resistances of all the bottles made on the previous day abnormally high. Took them all down and made up 3 more without rubber connections and with the zincs only 2 pots immersed on the ground that either the unvarnished copper or the rubber might possibly have some bearing on the results.

XL IV Amalgamated zincs. Chemical room solution heated to 70° and zincs then inserted.

XL V Amalgamated zincs. Chemical room solution heated to 80° and zincs then inserted

XL VI Amalgamated zincs. Chemical room solution heated to 90° and zincs then inserted.

Table showing behavior of the resistance of bottles.

No of bottle	Date of Inspection	Varnish	Solution	Plates removed or not	Surface Weak	19.11.98 26.0°	20.11.98 19.0°	21.11.98 16.5°	22.11.98 20.5°	23.11.98 20.5°	24.11.98 21°	26.11.98 21°	27.11.98 25.5°	28.11.98 26.5°	30.11.98 23.5°	1.12.98 21°	3.12.98 20.5°	5.12.98 18.5°	6.12.98 24.5°	11.12.98 27°	14.12.98 26.5°	22.12.98 22°			
VI 25	31. 10.98	Nordo	heated to 80°	after cooling	2.8 mm 18.11.98	1.8	2.6	2.7	1.99	2.75	1.95	1.60	1.30	1.25	1.35	1.45	1.35	2.05	1.05	1.00	0.88	0.92			
VII 25	31. 10.98	Nordo	not heated	—	7.1.25° 18.11.98	30.0	40.0	50.0	39	50.	40.	37.	31.0	30.0	36.	40.	44.	50	40	20	42.	50			
VIII 25	9. 11.98	Nordo varnish	not heated	—	8.2.25° 19.11.98	3.2	12.2	7.0	16.7	23.25	16.75	16.75	15.95	15.75	14.75	22.75	22.25	24.	19.5	17.25	20.25	28			
IX 25	9. 11.98	Nordo varnish	not heated	—	30.2.25° 19.11.98	30.0	51.0	56.0	44.	55.	24.25	27.	23.	23.	16.	50	52.	34.	22.5	22.25	26.75	30			
X 25	14. 11.98	Nordo	heated 100°	after cooling	2.2.25° 18.11.98		2.2	2.0	1.74	2.00	1.60	1.55	1.15												
XI 25	14. 11.98	Nordo	heated 100°	after cooling	2.2.25° 18.11.98		2.8	2.25	1.94	1.95	1.40	1.45	1.15												
XII 25	14. 11.98	Nordo	heated 100°	after cooling	2.2.25° 18.11.98		2.2	2.0	1.84	2.10	1.65	1.60	1.25												
XIII 25	14. 11.98	Nordo	heated 100°	after cooling	2.7 7° 20.11.98		2.09	2.70	2.44	2.15	2.05	2.00	1.65												
XIV 25	14. 11.98	Nordo	heated 100°	after cooling	2.25 1° 20.11.98	1.16	2.2	2.70	2.09	2.10		2.05	1.35												
XV 25	14. 11.98	Nordo	not heated	—	2.25 7° 20.11.98	1.24		2.65	2.66	2.25		2.00	1.75												
XVI 25	20. 11.98	Nordo	not heated	—	3.64 1° 20.11.98		3.64	3.55	2.99	3.25		2.50	2.15	2.25	2.55	2.75	2.75	3.20	2.95	2.75	2.95	3.35			
XVII 25	20. 11.98	Nordo	heated 100°	after cooling	2.25 18° 20.11.98		2.24	2.60	3.80	2.25		2.65	2.35	2.25	2.70	2.55	3.45	3.45	3.05	3.25	10.75	37			
XVIII 25	20. 11.98	Nordo	heated 100°	after cooling	2.25 15° 20.11.98		2.24	2.60	3.99	2.95		3.65	2.55	2.75	2.55	2.75	3.05	3.35	2.05	14.25	14	100			
XIX 25	20. 11.98	Nordo	heated 100°	heated in bottle	2.25 12° 20.11.98		11.24	10.82	7.24	3.35		2.05	3.25	3.75	2.15	2.45	5.75	7.25	7.95	14.25	26	95			
XX 25	20. 11.98	Nordo	heated 100°	heated in bottle	7.25 15° 20.11.98			7.24	2.24	2.30	3.55	1.95	1.80	1.90	2.55	2.65	3.25	4.75	5.35	15.25	22				
XXI 25	20. 11.98	Nordo	heated 100°	heated in bottle	2.25 15° 20.11.98			2.25	1.94	2.10	1.75	1.80	1.60	1.65	2.05	2.35	2.95	4.25	7.15	12.75	20				
XXII 25	22. 11.98	varnish	not heated	—	7.75 15° 23.11.98					7.75	7.45	9.25	7.75	8.35	6.75	6.45	3.65	5.75	6.65	7.75	10.0	14			
XXIII 25	22. 11.98	varnish	not heated	—	6.55 15° 23.11.98					6.25	10.15	8.75	6.75	6.15	11.55	16.75	20.0	26.	12.25	11.75	17.75	20			
XXIV 25	22. 11.98	varnish	not heated	heated in water bath	5.55 15° 23.11.98					5.55	15.75	22.75	10.75	10.65	15.75	23.25	24.	32.	22.	22.	29.25	26			
XXV 25	22. 11.98	varnish	heated to 90°	heated in bottle	5.05 15° 23.11.98					5.05	2.00	1.65	2.15	1.50	1.95	2.25	2.95	5.75	15.25	29.25	43				
XXVI 25	22. 11.98	varnish	heated to 90°	heated in bottle	4.95 15° 23.11.98					4.95	5.50	7.55	5.15	3.65	4.25	5.15	4.45	4.95	3.45	2.95	3.25				
XXVII 25	22. 11.98	non varnish	heated to 90°	after heating	3.25 25° 24.11.98					3.25	2.85	1.95	1.75	1.65	1.80	2.75	2.85	16.85							
XXVIII 25	22. 11.98	- - -	heated to 90°	after heating	2.55 25° 24.11.98					2.55	2.10	2.05	2.00	1.90	2.25	2.25	2.25	2.25							
XXIX 25	22. 11.98	- - -	heated to 90°	after heating	2.25 25° 24.11.98					2.25	1.95	1.75	1.65	1.80	1.95	1.75	2.25								
XXX 25	22. 11.98	nordo	heated to 100°	after heating	1.75 25° 24.11.98							1.75	1.30	1.05	2.05	1.85	1.65	0.95	0.80	0.75	3.20				
XXXI 25	22. 11.98	nordo	heated to 100°	—	3.25 25° 24.11.98							3.25	3.50	3.00	—	—	—								
XXXII 25	22. 11.98	nordo	heated to 100°	—	2.95 25° 24.11.98								2.95	2.05	3.25	2.35	2.25	2.05	2.15	11.75	25				
L 25	30. 11.98	nordo	heated to 100°	—	1.95 26° 28.11.98								1.95	1.50	1.65	1.55	1.55	1.25	1.15	1.65	3.25				
LI 25	30. 11.98	nordo	- - -	- - -	1.95 26° 28.11.98								1.95	2.65	2.45	2.65	2.55								
LII 25	30. 11.98	nordo	- - -	- - -	1.65 26° 28.11.98								1.65	1.90	1.95	2.30	2.30	1.75							
LIII 25	30. 11.98	nordo	- - -	- - -	1.60 26° 28.11.98								1.60	1.85	1.95	2.15	2.25	1.75							
LIV 25	23. 11.98 heated	nordo	not heated	commencing	4.11 24° 25.11.98								4.11	2.65	2.25	2.75	2.65	2.10							
LV 25	23. 11.98	nordo	- -	- - -	3.05 24° 25.11.98								3.05	2.25	3.15	3.45	2.85	2.15							
LVI 25	23. 11.98	nordo	- -	- - -	5.00 24° 25.11.98								5.00	2.85	3.25	5.20	2.85	1.35							
LVII 25	23. 11.98	nordo	- -	- - -	1.60 24° 25.11.98								1.60	1.55	1.65	1.65	2.25	1.75							
LVIII 25	5. 12.98	nordo	heated to 100°	not heated	14.45 24° 6.12.98													14.45	2.0						
LIX 25	5. 12.98	nordo	- - -	5% by weight	2.05 24° 6.12.98													2.05	1.12	2.25	4.25				
LX 25	5. 12.98	nordo	- - -	5% by weight	9.05 24° 6.12.98													9.05	3.32	2.85	3.05				
LXI 25	5. 12.98	nordo	- - -	5% by weight	2.95 24° 6.12.98													2.95	1.22	2.95					
LXII 25	5. 12.98	nordo varnish	- - -	5% heated to 100°	4.95 24° 6.12.98													4.95	3.85	6.75	50				
LXIII 25	5. 12.98	nordo varnish	- - -	5% heated to 100°	3.45 24° 6.12.98													3.45							
LXIV 25	5. 12.98	nordo varnish	- - -	5% heated to 100°	5.25 24° 6.12.98													5.25							

Phonograph battery tests.

The trials of the new pattern of Chromic acid battery were made as follows:-

On November 15th Two cells of size as described on page 10 were fitted with pressed Gravit carbons in plate form instead of the previous arc carbons. The curves obtained from the observation of their performance on that date were preserved. The EMF being rather low, another trial was made on the following day (16th) with real Gravit cut carbons, and the results are shewn in the subjoined table as Line III. The curve is recorded on the same sheet as that giving I and II. Lastly the zincs having been reduced in dimensions to 5cms X 12.7 X 1 cm another run was made on the 20th the main facts relating to which are stated on line IV. The curve pertaining to this was also preserved.

No.	Date	Style of Cell	at 2 Amt EMF	I.R.	C.	after 6 hours EMF	I.R.	C	after 12 hours EMF	I.R.	C.
I & II	15.11.88		1.98	0.04	3.7	1.88	0.07	3.2	1.78	0.12	2.9
III	16.11.88		1.97	0.058	3.5	1.88	0.07	3.2			
IV			2.025	0.062	3.55	1.88	0.07	3.25	1.82	0.13	2.95
V											

Meter Experiments contd.

November 26th Monday.

Two more solutions made up as follows:-

XLVII Two previously used 25 zinc plates reamalgamated in the usual way and heated in bottle of chemical room solution to 90°C on sand bath. Zincs varnished but tops out of liquid.

XLVIII Two previously used 25 zinc plates reamalgamated after heating in incubator to about 100°C, i.e. amalgamated hot. and again heated in similar o.r. solution to 100°C.

Since both these pairs of zinc plates lost their lustre after the heating of the bottles they were removed while the liquid was still hot and reamalgamated and then quickly replaced. They then retained their metallic lustre and accumulated bubbles on their surface.

Meter Experiment November 27th Tuesday.

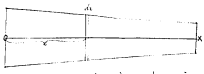
Two more solutions made up as follows:-

XLIX Two 25 zinc plates, old and well worn from commercial use were amalgamated then heated to 100°C in $ZnSO_4$ solution & reamalgamated. They were then immersed in solution that had been heated to 100°C and cooled.

~~XL~~ L Two new 25 zinc plates other particulars and treatment same as last XLIX

Problem.

To find the resistance of a homogeneous solid conductor in the form of a right conic frustum between the terminal circular surfaces, having given the specific resistance of the material, the length of the axis and the terminal radii.



Let O be the centre of one of the terminal circles and the origin of coordinates, OX the length of the frustum

ρ = the radius at any point

ρ = the spec: res: of the material

x = any distance from O measured along OX

Then the resistance dR of any elementary lamina is

$$dR = \frac{\rho\,dx}{\pi\rho^2} \quad \text{but } r = f(x) = ax + b \text{ suppose}$$

Then $dR = \dfrac{\rho\,dx}{\pi(ax+b)^2}$

Thus $R = \int_0^X \dfrac{\rho\,dx}{\pi(ax+b)^2} = -\dfrac{\rho}{\pi}\left\{\dfrac{1}{a(aX+b)} - \dfrac{1}{a(a\times 0+b)}\right\}$

$$= \frac{\rho}{\pi} \times \frac{aX}{b(aX+b)} = \frac{\rho}{\pi}\frac{X}{b\,r_2} = \frac{\rho X}{\pi(r_2 r_1)}$$

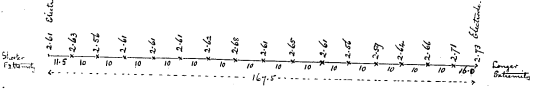
so that instead of taking the arithmetical means of the terminal radii for the radius of the mean area, the geometrical mean is mathematically the correct one.

Specific Resistance and Temp: Coeff: of $ZnSO_4$ solution contd.

(4/6)

Since it might be possible to question the accuracy of the spec: res: obtained on the ground that the mean area of the tube employed was not determined with sufficient accuracy, I took it down and measured its diameter at every 10 cms: in the following way.

A glass tube about 15 cms in diam: and some 150 cms long was supported on a temporary pivot at its centre of length and its two ends were fitted with corks. One end carried in the cork a vertical wire 2·42 cms by scale and 2·408 by micrometer length say 2·4112 or 2·4112 ± 0·0027. At the other end a pin issuing horizontally from the cork moved by the side of a vertical cm: scale. The tube to be tested was passed over the first end of this measuring tube and the free vertical play of the wire end was measured by the corresponding movement of the pin over the scale. The following diagram represents the diameter thus found.



Assuming there a series of conic frustra we have

$$R = \frac{\rho}{\pi}\left\{\frac{l_1}{r_1 r_2} + \frac{l_2}{r_2 r_3} + \frac{l_3}{r_3 r_4} + \qquad + \frac{l_n}{r_n r_1}\right\} = \frac{\rho\, l}{\pi\, \bar{\sigma}^2}$$

$$\therefore \pi\sigma^2 = \frac{\frac{1}{2}\pi l}{\frac{l_1}{r_1 r_2} + \frac{l_2}{r_2 r_3} + \frac{l_3}{r_3 r_4} + \qquad + \frac{l_n}{r_n r_1}}$$

No. of section	l	d	d_1	$\frac{l}{r_1 r_2}$	$\Sigma \frac{l}{r_1 r_2}$	No. of section	l	r	r_1	$\frac{l}{r_1 r_2}$	$\Sigma \frac{l}{r_1 r_2}$
1	11·5	2·61	6·862	1·676		9	10	2·61	6·915	1·4466	
2	10	2·63	6·732	1·485		10	10	2·65	6·915	1·4466	
3	10	2·56	6·682	1·497		11	10	2·61	6·681	1·497	
4	10	2·61	6·812	1·468		12	10	2·56	6·630	1·508	
5	10	2·61	6·812	1·468		13	10	2·59	6·837	1·462	
6	10	2·61	6·837	1·462		14	10	2·64	7·024	1·425	
7	10	2·62	7·020	1·425		15	10	2·66	7·268	1·387	
8	10	2·68	6·994	1·429	11·99 Ω	16	16·0	2·71	7·398	2·1632	12·39 Ω
	51·5	2·61	6·812				56·0	2·72			
											24·24

$$\frac{\cancel{\pi} \times 3{\cdot}14416 \times 167{\cdot}5}{4 \times 24{\cdot}24} = \frac{526{\cdot}2}{96{\cdot}96} = 5{\cdot}427 \text{ sq cms mean area.}$$

The result agrees with the previously accepted one to within 1%.

To take it would seem to reduce the calculated spec: res: under 1%.

Meter Experiments contd:— November 27th Tuesday

Took down meter bottles which have been at work since the 19th and weighed plates

Bottle	Position	Air-bag	Plate	Weight simply	Sample weight	Weight 19.11.11	Gain	Loss	Loss corrected for blank	Ratio of Gain/Loss	% error	Average % Error
XVII	Standard #1		1	85·1812	0.1236	85·6353						
			2	90·2747	175·4276 / 175·4702	89·8347	0·4400	0·4541 / 0·1141	0·4566	1·0013		
XVIII	Standard #2		3	88·1450	177·8267	88·9013						
			4	89·3447	177·8107 / 0·1106	88·9254	0·4393	0·4563 / 0·1198	0·4572			
XIX	Conf. Standard		5	81·1333	169·1270	81·1425						
			6	88·0242	169·1585 / 168·0882	88·0444	0·	0·0092 / 0·2293 / 0·2293	0·2293			
XX	Meter #2 A warm		7	81·4320	172·0913	81·8796						
			8	90·6536	172·0886 / 0·0226	90·2112	0·4422	0·4456 / 0·0324		(1·026 / 0·978)	2·5% warm + heated	1·65
XXI	Meter #1 A cold		9	88·6088	178·1460	89·0541						
			10	89·8336	178·1358 / 0·1105	89·3920	0·4415	0·4533 / 0·1173		(1·008 / 0·992)	0·8% cold + heated	1·37
XXII	Meter #2 B warm		11	91·1769	180·2741	91·6107						
			12	89·0660	180·2428 / 0·0298	88·6418	0·4242	0·4348 / 0·1106		(1·051 / 0·951)	4·9% warm + not heated	1·8
XXIII	Meter #1 B cold		13	87·1940	169·2161	87·6482						3·85
			14	82·0556	169·2102 / 0·0059	81·5681	0·4475	0·4442		(1·029 / 0·972)	2·8% cold + not heated	

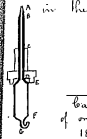
November 28th Wednesday

Mr West having brought with him 6 bottles that had been set up commercially at Pearl St., the meter test was commenced with them and the standards at 10 o'clock, some 50 hours after the Pearl St bottles had been set up.

Bottle	Position	Plates	Solution	Weight simply	Sums of samples	Observed wt. of water	Discrepancy	Observer			
I	Conf. Std.	Previously tst	heated	(1) 88·9887 (2) 87·3990	176·3877	176·3887	+0·0010	A.E.K.			
II	Std #1	" -	-	(3) 89·0018 (4) 90·1742	179·1760	179·1750	-0·0010	-			
III	Std #2	- -	-	(5) 89·2789 (6) 84·3411	173·6200	173·6210	+0·0010	-			
IV	Meter #1 cold	Commercially	not heated	(1) 79·310				Pearl St			
V	"	-	- -	(2) 76·400				-			
VI	Meter #2 warm	-	- -	(3) 82·625				-			
VII	- -	-	- -	(3a) 80·010				-			

Experiments on the resistance of zinc sulphate solution

To ascertain whether the resistance of $ZnSO_4$ solution altered under pressure I took the bailliet apparatus and arranged to fill a tube with the solution insert a zinc plated wire in the top and seal them into resistance of column of liquid between the wire and the mercury in the chamber and apply pressure.



Lengths				
Top A to shoulder B internally	5·3	External Diam	1·2	outer tube.
Shoulder B to Collar C .	15·5	Internal -	0·25	
Shoulder B to Shoulder D .	27	External .	2·0	
Shoulder D . . F .	23			
Total length from top A to arm E	57·5			

Calibrations.

of one tube L.C.N. drawn compared with bell tube whose vol: per cm = 0.2662

18 cms of pressure tube equal 4·35 cms of bell tube in capacity = 0·0649 c.c.

17 - - - - - 3·90 . - - - - - - = 0·0619 . .

15·5 - - - - - 3·90 . - - - - - - = 0·0676 . .

15 - - - - - 3·70 . - - - - - - = 0·0662

0·0652

No. of obs.	Obs: from	Mean	Residual	r^2	Σr^2	$\sqrt{\Sigma r^2}$	$0.6745\sqrt{\frac{1}{n(n-1)}}$	γ	Calculated Accu	Diam
1	0·0649	0·0652	+0·0003	9.0×10^{-8}	1774×10^{-7}	42.1×10^{-4}	0·1947	0·00082	0·0652 ±	±288
2	0·0619		+0·0033	109.9×10^{-8}					0·0001	
3	0·0676		-0·0024	576×10^{-8}		0·0042				
4	0·0662		-0·0010	100×10^{-8}						

The first test was made on the 24th Nov: when however no very accurate readings could be obtained. About 20 cms: of the fine tube contained $ZnSO_4$ solution having a density of 1·18 @ 20°. Its spec: res: being about 230 the res: of this column would be $\frac{23 \times 230}{0.065}$ or 7076 and the actual res: observed was about 8000 Ω. On applying pressure, the res: fell rapidly and after about 100 atmosphere was reached the res: was about 6000 Ω, a fall of 25%. There was however air in the tube, perhaps 1 c.c. above the liquid column, and the heat generated by the pressure and condensation of this would probably account for the great diminution. The seal gave way at 180 atmosphere. The next test took place with the same tube on the same day. The seal of the electrode was this time so contrived that no air remained imprisoned. The following results were obtained with about 20 cms: of the same solution calculated to give about 7080 Ω.

No. of Pt	Time	Current thro test tube	Res: obsd	Pressure	Temp: air	Press: in atmospheres	Δr	Δz	Δr/Δz	
1	21.30	1 ma	6970	1 atm	20°	1.01	15	4.04	3.71	
2			6955	5		5.05	5	7.07	0.71	
3			6950	12		12.12				
4			6940	25		25.25	10	13.	0.77	
5			6935	36		36.36	5	11	0.45	
6			6932	50		50.5	3	14	0.21	

Experiments on the resistance of zinc sulphate solution under

These experiments were continued on the 30th November as follows—

The Bunsen tube was this time exhausted after the plated wire had been sealed in it, and the lower end sealed. The seal was then broken under $ZnSO_4$ solution (pure slightly acid and of sp.g. 1.178 @ 23.6°.C.) The temp. of the water in the press was about 23°.C. When the tube had filled with the solution a little mercury was introduced into the lower bend and the whole steadily forced into the mercury both after a zinc plated and amalgamated platinum wire had been thrust up into the tube almost to the shoulder D. thus leaving a column of about 23 cms. in ext. between the electrodes. This would mean an estimated resistance of 8500 ω, and the observed resistance was about 10,600.

	Bridge	Time	Indicated Pressure	Obd. Res.	Obd. res. for T.B.	Δt	Δp	$\frac{\Delta r}{\Delta p}$	Pressure in atmos.	Corrected value of Δp	Ratio $\frac{r_p}{r_{p'}}$
1	Bridge 10	16.00	1.	10640	10,670				1.01	1	1.0272
2			6	10650	10680				6.06		
3			12	10640	10670				12.12		
4			16	10640	10670				16.16		
5			20	10640	10670				20.2		
6			25	10640	10670				25.25		
7			5	10680	10710	40	−20	−2.0	5.05	−2.0	
8			25	10640	10670				25.25		
9			30	10640	10670				30.3		
10			35	10640	10670				35.35		
11			40	10630	10660				40.4		
12			45	10620	10650						
13			50	10610	10640				45.45		
14									50.5		
15			5	10690	10720	80	−45	−1.8	5.05	−1.8	
16			25	10650	10680	−40	+20	−2.0	25.25		
17			50	10620	10650	−30	+25	−1.2	50.5		
18			55	10610	10640	−10	+5	+2.0	55.5		
19			60	10600	10630	−10	+5	−2.0	60.6		
20		16.15	65	10600	10630				65.7		
21		.16	70	10590	10620				70.7		
22		.18	75	10580	10610				75.8		
23		.18	5	10700	10730	+120	−70	−1.7	5.1	−1.7	
24		.25	5	10790	10820				5.1		
25		30	5	10790	10820				5.1		
26		.30	25	10760	10790	−30	+20	−1.5	25.3	−1.5	
27		.30	55	10710	10740	−50	+30	−1.7	55.6	−1.7	
28		.31	75	10670	10700	−40	+20	−2.0	75.8		
29		.31	85	10650	10680	−20	+10	−2.0	85.9		
30		.31	95	10630	10660	−20	+10	−2.0	96.0		
31		.32	100	10620	10650				101		
32		.33	110	10600	10630				111		
33		.33	120	10590	10620				121		
34		.33	135	10570	10600				136		
35	Bridge $\frac{1000}{100}$	.34	150	10540	10570				152		
36		.34	160	10530	10560				162		
37		.35	170	10510	10540	−280	+165	−1.7	172	−1.7	
		.36	175	Tube seal broke.							

$\frac{EX}{r}$ = 0.73 mutiplied by this pressure tube. T.B. 27.1°

80 mms. giving the bridge coeff. of reduction for bridge $\frac{1000}{100}$

It is evident from these results that the resistance of the column decreased 1·7 in 10700 or 0·00159 % for every additional atmosphere.

If this was due to an enlargement of the glass by the pressure, then $a_p : a :: r_p^2 : r_{p'}^2$

$\therefore 10701.7 : 10700 \quad \therefore r_p = r\sqrt{\frac{10701}{10700}} \quad r\sqrt{1.00001551} \quad r \times 1.000079$ = 0·008 % radial expansion per atmosphere

With a constant friction on the pivots the equation of motion becomes:-

$$\frac{d^2\theta}{dt^2} = -\frac{E\theta}{Mk^2l} \pm \frac{f}{Mk^2}$$

which becomes $\frac{d^2\theta}{dt^2} = -a\theta \pm b$ where $a = \frac{E\theta}{Mk^2l}$ and $b = \frac{f}{Mk^2}$

$$\therefore \quad 2\frac{d\theta}{dt}\frac{d^2\theta}{dt^2} = -2a\theta\frac{d\theta}{dt} - 2b\frac{d\theta}{dt}$$

$$\therefore \quad \left(\frac{d\theta}{dt}\right)^2 = -a\theta^2 - 2b\theta + c \quad \text{where } c \text{ is defined by the condition}$$

That when $\frac{d\theta}{dt} = 0$ $\theta = 0$ and $\theta = \varphi$ the limiting angle

$$\therefore \quad 0 = -a\varphi^2 + c$$

$$\text{or } c = a\varphi^2$$

$$\therefore \quad \left(\frac{d\theta}{dt}\right)^2 = -a\theta^2 - 2b\theta + a\varphi^2$$

$$\text{and } \frac{d\theta}{dt} = \sqrt{a(\varphi^2 - \theta^2) - 2b\theta}$$

$$\therefore \quad dt\frac{dt}{d\theta} = \frac{d\theta}{\sqrt{a\varphi^2 - 2b\theta - a\theta^2}}$$

$$\therefore \quad \int_{-\varphi}^{+\varphi} dt\frac{dt}{d\theta} = \int_{-\varphi}^{+\varphi}\frac{d\theta}{\sqrt{\alpha + 2\beta\theta - \gamma\theta^2}} \quad \text{where } \alpha = a\varphi^2,\ \beta = -b,\ \gamma = a$$

$$= \frac{1}{\sqrt{a}}\left\{\sin^{-1}\frac{\gamma\varphi - \beta}{\sqrt{\alpha\gamma + \beta^2}} - \sin^{-1}\frac{-\gamma\varphi - \beta}{\sqrt{\alpha\gamma + \beta^2}}\right\}$$

$$= \frac{1}{\sqrt{a}}\left\{\sin^{-1}\frac{a\varphi + b}{\sqrt{a^2\varphi^2 + b^2}} - \sin^{-1}\frac{-a\varphi + b}{\sqrt{a^2\varphi^2 + b^2}}\right\}$$

$$= \frac{1}{\sqrt{a}}\left\{\sin^{-1}\sqrt{\frac{a^2\varphi^2 + b^2 + 2ab\varphi}{a^2\varphi^2 + b^2}} - \sin^{-1}\sqrt{\frac{a^2\varphi^2 + b^2 + 2ab\varphi}{a^2\varphi^2 + b^2}}\right\}$$

$$= \frac{1}{\sqrt{a}}\left\{\sin^{-1}\sqrt{1 + \frac{2ab\varphi}{a^2\varphi^2 + b^2}} - \sin^{-1}\sqrt{1 + \frac{2ab\varphi}{a^2\varphi^2 + b^2}}\right\} \quad \text{where } h = \frac{2ab\varphi}{a^2\varphi^2 + b^2}$$

$$= \frac{1}{\sqrt{a}}\left\{\sin^{-1}\sqrt{1 + h} - \sin^{-1}\sqrt{1 + h}\right\}$$

$$= \frac{1}{\sqrt{a}}\left\{\sin^{-1}\left(1 + \frac{h}{2} - \frac{h^2}{8} + \frac{h^3}{16}\right) - \sin^{-1}\left(1 + \frac{h}{2} - \frac{h^2}{8} + \frac{h^3}{16}\right)\right\} \quad \text{rejecting } 3rd \text{ \& higher powers}$$

$$= \frac{1}{\sqrt{a}}\left[\left(\frac{\pi}{2} + \Delta\right) - \left(\frac{\pi}{2} - \Delta\right)\right]$$

$$= \frac{1}{\sqrt{a}}\,\pi$$

$$\therefore \quad T = 2\pi\sqrt{\frac{MK^2l}{E}} \quad \text{as before to the 1st approximation.}$$

Record supplied by Mr Wirt of a test made by him of the insulating power of asbestos shielding. 27th November. 1888.

A brass tube 6·4 cms ext. diam. and 47·5 cms long was covered centrally by a sheet of asbestos paper 21·5 cms wide, 28·5 cms long and 0·175 cms thick. This split outer asbestos tube was then tightly overwound with bare copper wire laid up close. The area of asbestos thus interposed under metallic pressure was 21·5 × 28·5 = 613 sq. cms. The res. between the wire and brass tube was at first 47000 but lying over the steampipes for about an hour this rose to over 10.
When so supported over two bunsen burners and in their flames for 15 mins, the defl. by trigs above 12 was 150 and below inf. 10. It is certain that the part of the outside of sample in the flame was up to dull red temperature.

On a calculation of the time of oscillations of a pendulum

Let m be the mass of the small bob
l . . length of the thin string
φ . . semiarc of oscillation
θ . . angle of deviation at any moment
s . . arc
h . . elevation of the c.g. of m at φ
g . . acceleration of gravitation

Then $\frac{d^2\theta}{dt^2} + \frac{g}{l}\sin\theta = 0$ and when θ is small this is practically the same as $\frac{d^2\theta}{dt^2} + \frac{g\theta}{l} = 0$

$$\therefore \quad 2\frac{d\theta}{dt}\frac{d^2\theta}{dt^2} = -\frac{2\theta}{dt}\frac{g\theta}{l}$$

$$\therefore \quad 2\left(\frac{d\theta}{dt}\right)^2 = -\frac{g}{l}\theta^2 + c$$

c is defined by the condition that when $\theta = 0$, $\frac{m}{2}\left(\frac{d\theta}{dt}\right)^2 = mgh = mg\frac{\varphi^2}{l} = \frac{mg}{l}l^2\varphi^2$

$$\therefore \quad \left(\frac{d\theta}{dt}\right)^2 \text{ then } = \frac{g}{l}\varphi^2$$

$$\therefore \text{ generally } \left(\frac{d\theta}{dt}\right)^2 = \frac{g}{l}(\varphi^2 - \theta^2)$$

$$\therefore \quad \frac{d\theta}{dt} = \sqrt{\frac{g}{l}(\varphi^2 - \theta^2)}$$

But the time occupied by a semioscillation is

$$\int_{-\varphi}^{+\varphi}\frac{dt}{d\theta} = \int_{-\varphi}^{+\varphi}\frac{dt}{d\theta}\,d\theta = \int_{-\varphi}^{+\varphi}\sqrt{\frac{l}{g}}\sqrt{\frac{1}{\varphi^2 - \theta^2}}\,d\theta$$

$$= \sqrt{\frac{l}{g}}\int_{-\varphi}^{+\varphi}\frac{d\theta}{\sqrt{\varphi^2 - \theta^2}} = \sqrt{\frac{l}{g}}\,\sin^{-1}\frac{\theta}{\varphi}\Big]_{-\varphi}^{+\varphi} = \sqrt{\frac{l}{g}}(\sin^{-1}1 + \sin^{-1}1)$$

$$= \sqrt{\frac{l}{g}}\,2\frac{\pi}{2} = \pi\sqrt{\frac{l}{g}} \quad \text{so that a complete period} = 2\pi\sqrt{\frac{l}{g}}$$

For a simple watch spring the equation of motion is approximately

$$\frac{d^2\theta}{dt^2} = -\frac{E\theta}{MK^2l}\theta \quad \text{where } M \text{ is the mass of the balance wheel + spring}$$

K . . radius of gyration
l . . length of the spring
E . . coefficient of rigidity

$$\therefore \text{ as before } T = 2\pi\sqrt{\frac{MK^2l}{E}}$$

With an opposed electrodynamic force of $2a\frac{d\theta}{dt}$ resisting the motion the equation becomes, neglecting friction.

$$\frac{d^2\theta}{dt^2} + 2a\frac{d\theta}{dt} + b\theta = 0 \quad \text{where } b = E/MK^2l \qquad (1)$$

Assuming that $\theta = ce^{mt}$ we have the auxiliary equation

$$m^2 + 2am + b = 0 \quad \text{The solution of which gives}$$

$$m = -\frac{a}{2} \pm \frac{\sqrt{a^2-4b}}{2} \qquad (2)$$

Since b is about 1000 and a is small relatively to it, these roots are imaginary and are $= -\alpha \pm \beta(I-I)$ where $\alpha = \frac{a}{2}$ and $\beta = \sqrt{b-a^2}$ and the general solution of the differential equation is

$$\theta = Ae^{-\alpha t}\cos\beta t + Be^{-\alpha t}\sin\beta t \qquad (3)$$

When $\theta = +\varphi$ let $t = 0$ and $\frac{d\theta}{dt} = 0$ (4)

also when $\theta = 0$ - $t = \frac{\tau}{2}$ - $\frac{d\theta}{dt} =$ a maximum (5)

- $\theta = -\varphi$ - $t = \tau$ - $\frac{d\theta}{dt} = 0$. (6)

Then since $\frac{d\theta}{dt} = -Aae^{-\alpha t}\cos\beta t - A\beta e^{-\alpha t}\sin\beta t - Bae^{-\alpha t}\sin\beta t + B\beta e^{-\alpha t}\cos\beta t$ (7)

Then by (4) $\therefore 0 = -Aa + B\beta$ (8)

and by (3) $\varphi = A$ φ being the limiting angle. (9)

$\therefore B = \frac{a}{\beta}\varphi$ (10)

and the solution is $\theta = \varphi e^{-\alpha t}\cos\beta t + \frac{a\varphi}{\beta}e^{-\alpha t}\sin\beta t.$ (11)

Since θ at $t = 0$ $= -\theta$ at $t = \tau$

we have $\varphi = -\varphi\left\{e^{+\alpha\tau}\cos\beta\tau \mp \frac{a}{\beta}e^{+\alpha\tau}\sin\beta\tau\right\}$

$\therefore 1 = -e^{+\alpha\tau}\cos\beta\tau + \frac{a}{\beta}e^{+\alpha\tau}\sin\beta\tau$

$\therefore \cos\beta\tau = \frac{-1}{e^{+\alpha\tau}} + \frac{a}{\beta}\sin\beta\tau$

$= -e^{-\alpha\tau} + \frac{a}{\beta}\sin\beta\tau$

when a vanishes this $= -1$

and $\beta\tau = \cos^{-1}(-1) = \pi$

$\therefore \tau = \frac{\pi}{\sqrt{b}}$

but when a is not zero $\tau = \frac{1}{\beta}\cos^{-1}\left(-e^{-\alpha\tau} \mp \frac{a}{\beta}\sin\beta\tau\right)$

a result which is meaningless for $\mp$ values of a.

The quantity $\frac{a}{\beta}\sin\beta\tau$ is very small and neglecting it

$$\tau = \frac{1}{\beta}\cos^{-1}\left(-e^{-\alpha\tau}\right)$$

Multipolar Dynamo Test.

December 3rd Monday.

10.50 Commenced running multipolar direct from #1 engines no other belt or shafting being driven.
The field magnet coils in 4 sets of 4 coils each.

10.57 Speed about 820 revs. per min. Volts 160 Amperes in field 4.2

Time	Hours at stay-bolts	Length No. of coils	Mhos. reading	Field Current	Current in Coils	Volts at M.T.	Speed	Amperes	Deflection on 35 mm	Amperes by Cond.	
10.57	0.00	2	0.66	4.2	10.5	160	820	.95	25	196	
11.00	.03	4	1.32	40.5	10.1	155		220	48	205	
.03	.04	6	1.98	37	9.2	149		270	69	298	
.05	.06	8	2.64	36	9.0	143		370	80	378	
.07	.10	10	3.3	35	8.8	139		425	92	459	
.09	.12	12	4.0	34.5	8.6	135		—	102	540	
.11	.14	14	4.66	32	8.0	129		—	109	600	
.12	.15	16	5.33	30.2	7.6	127		—	115	677	
.14	Stopped for adjustment. Highest temp. reached on armature 135°F. Remove bolt										
12.00	Started running again having displaced mains.										
.01	0.01	2	0.66	39	9.75	160	820	—	22	107	
.02	0.02	6	2.0	37	9.25	149		—	48	298	
.03	0.03	10	3.3	36.5	9.1	138		—	86	445	
.04	0.04	14	4.66	32.2	8.1	136.5		—	110	636	
.06	0.06	18	6.0	28.7	7.2	115		—	130	690	
.10	0.10	22	7.3	26.2	8.7	107		—	148	781	
13.00	1.00	22	7.3	25	6.25	105		—	120	747	
	Stopped on account of hot bearing. Highest temp. reached 205°F.										
15.30	0.00	2	0.66	41	10.03	160	820	.95	28	107	
.35	0.05	6	1.98	37	9.25	150	—	280	50	300	
.40	0.10	10	3.3	33	8.25	138		430 = 320	78	460	
.43	0.13	18	6.0	29	7.00	120		300 = 587	115	720	
.45	0.15	20	6.7	27	6.75	114		360 = 673	114	760	
.50	0.20	22	7.3	25	6.25	109		370 = 692	125	791	
.55	0.25	26	8.7	24	6.0	102		385 = 720	109	720	
16.00	0.30	19	6.3	25	6.25	101		340 = 636	95	636	
.12	0.42	19	6.3	23.5	5.9	104		335 = 627	83	636	
.40	0.10	19	6.3	24	6.0	100		335 = 627	85	620	
17.30	Stopped to alter arrangement of magnet coils + on account of steam. Highest temp. reached 221°F.										
	Arranged the coils in 5 sets of 3 with one extra one in whose circuit an ammeter and resistance box were also inserted.										
19.40	0.00	20	6.7	62	10.2	130		375 = 750	109	867	
20.10	.30	20	6.7	55	9.2	123		370 = 740	"	820	
21.10	1.30	Stopped to fit brushes. Highest temp. at 21.35 = 221°F.									
22.30	.00	Started again having fitted brushes									
22.30	.00	20	6.7	53	8.8	115		360 = 720	"	770	
23.30	1.00	20	6.7	48	8.0	110		350 = 700		730	
24.30	2.00	20	6.7	47	7.8	110	725	345 = 690		730	
25.00	2.30	20	6.7	44	7.3	102	720	325 = 650		680	steam low
2.00	3.30	20	6.7	45	7.5	103	705	325 = 650		655	" " 660
3.00	4.30	20	6.7	45	7.5	104	730	325 = 650		693	" "
	Stopped to fit brushes. Highest temp 250°F.										
4.30	0.00	20	6.7	57	9.5	120	790	375 = 750		800	
5.30	1.00	20	6.7	49	8.2	113		360 = 720		763	
6.00	1.30	20	6.7	48	8.0	112	700	360 = 720		750	
6.30	2.00	20	6.7	47	7.8	112		350 = 700		750	
7.00	2.00	20	6.7	47	7.8	112		350 = 700		750	Stopped

Water Tank 76°F.

Physiological Experiments.

December 4th Wednesday.

Cardew voltmeter Readings.

°	23°	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°	110° Resumed 100°	110°
	43	49.6 / 1.0	54.4 / 0.96	62.0 / 1.52	67.8 / 1.16	72.8 / 1.0	79.0 / 1.24	85.2 / 1.24	89.2 / 0.8	92.9 / 0.74	97.4 / 0.92	102.0 / 0.92	106.8 / 0.96	112 / 1.04	Catch lost 122	132

Res: of Cardew at 22°C 681 ω

Additional Platinum wire Resistance I 670 ω, I + II 2061 ω, I + II + III 4205 ω

Res of converter for occasion: Primary 0.09, Secondary 10.75

Took two g.p. covered wire into Ore-Milling House as mains

" " cotton " " " " " Field cot leads.

The Board appointed by the Medico-Legal Society arrived about 1¾ o'clock. Dr Dorcum, Professor Dourmer, Mr Gheny, Dr Peterson, Dr Ingram and Mr Brown being among the number. Two electrodes of metal covered with sponge were supplied by Dr Peterson. Connecting wire were soldered to them.

The animals provided for the occasion were a horse (photographed) weighing and 2 calves weighing respectively 124½ and 145 lbs.

Tried the first calf with the converter sent from N.Y., the coarse wire circuit being on the machine and the fine wire on the animal. The P.D. at the moment of making contact was indicated by 90° with 10 lamps of 230 ω each and the whole bound of 4200 in cct. 6500 ω in cct $= 112 - 11.2 = 100.8 \times \frac{6500 + 680}{680} = 101 \times \frac{7180}{680} = 1070$ say 1100.

Immediately after breaking the circuit the P.D. was 84° = 106 − 10.6 = 96 × 10.6 = 1015 say 1000.

During the contact which lasted for 30 seconds the deflection fell to about 25 which would mean perhaps 10 volts × 10.6 = say 100. $\frac{15 \times 100}{16 \cdot 25}$ $\frac{15 \times 100}{16 \cdot 25 \cdot 25}$

The animal fell unjigged.

Finding that the converter failed to sustain the E.M.F., used the current from the machine direct.

The voltage before making contact was 110° = 132 − 13 = 119 × 7 = 833

During contact the mean deflection was 100° = 122 − 12 = 110 × 7 = 770

The contact lasted 8 seconds. Breathing ceased in 1½ mins.

The resistance between the electrodes before death was 3200 ω approx.

Second calf weighing 145 lbs; Res between electrodes 1300 ω. 16.36 16.36.25

Direct action of the machine as before alternating 200 times per sec.

The voltages were 110° before contact = 833 and 98° during contact = 750.

Contact lasted for 5 seconds.

Breathing ceased in 1½ mins.

Horse, thrown, and its four feet tied together.

Tried converter to attain high momentary voltage but not successful. Obtained as high voltage that cardew gave way and so there unable to measure voltage used lamps.

With 10 lamps from converter = about 1000 volts gave momentary current the voltage falling immediately. Horse unjigged.

Resorted to machine current with 7 lamps not quite up to brilliancy say 600 volts. Contact made for 15 seconds. Horse subsequently struggles but not fatally injured. Renewed contact at full brilliancy of 7 lamps for 25 seconds. Respiration then very shortly ceased.

The contact on the calves were made on the forehead and by the side of the spinal column just behind the scapula on the fore leg. The electrodes were soaked in water solution and the hair was clipped. With the second calf cotton wads well soaked was added as a padding. In the case of the horse the electrodes consisted of bandages of soaked wads parcelled with tin wire on the fore leg above the knee.

Resistance of Zinc Sulphate solution under pressure contd —

December 5th Thursday

Since the diminution which has been visible in the resistance of zinc sulphate solution under pressure might be possibly due to expansion of the glass tube in air, the shape of the pressure-tube was altered so that the greater part of it was immersed in the pressure-chamber where it could receive equal pressures on the inside and outside.

Referring to the figure from A L B the wire was sealed a distance of about 1 cm.

Int Dia = 0.25 cm
Ext - 1.50
Wall thickness 0.53

B b C - wire with its amalgamated zinc surface passed into the liquid for about 2 cms, and the ends of the collar at C was about 0.3 cm from the end of the wire.

C b D the tube passed for 10.9 cms inside the collar.

D b E the tube continued for 15.5 cms.

E b F is 2 cms.

So that when an amalgamated zinc covered platinum wire was inserted at F and projected to E the length of the liquid column between the electrodes would be about 26.5 cms of which more than half was under both outside external as well as internal pressure. The following results were obtained with solution the same as that last used and recorded on page 44.

No of obs	Time	Bridge no.	Observed Pressure	Magnifying power by 1 cm.	Observed Res.	Calc for Temp	Δr	Δp	Δr/Δp	Coef of pressure Δr/Δp	Ratio
1	17.50		1	1.01	9630	9640					
2	.51		50	50.5	9560	9570	-70	+49	1.43		
3	.52		1	1.01	9640	9650	+80	-49	1.63	1.53	$\frac{R_1}{R_0} = 1.008$
4	.53		100	101.	9480	9490	-160	+99	1.62		
5	.56		1	1.01	9670	9680	+170	-99	1.72	1.67	$\frac{R_2}{R_0} = 1.019$
6	.57		150	152.5	9460	9470	-210	+149	1.41		
7	.59		1	1.01	9700	9710	+240	-149	1.61	1.51	$\frac{R_3}{R_0} = 1.025$
8	18.00		200	202.	8700	8710	-1000	+199	5.0		$\frac{R_4}{R_0} = 1.042$
9	.02		1	1.01	9070	9080	+370	-199	1.86		
10	.03		250	252.5	8600	8610	-470	+249	1.88	1.86	$\frac{R_5}{R_0}$
11	.04		1	1.01	9060	9070	+460	-249	1.84		
12	.05		300	303	8380	8390	-680	+299	2.27		

Bridge no. 6 = 0.6 mm
Bridge no. 4 = 1.2 mm
Temp of the tube T = 25.4° C.
Tube broke at 300

The following observations of variation of density with temperature were taken with heated water solution.

1.031	@ 78° C		
1.034	@ 70°	0.005 for 10°	0.0005 per °C
1.040	@ 60°		
1.045	@ 50°	0.005 - -	-
1.048	@ 45°		
1.050	@ 40°	0.005 - -	-
1.054	@ 27°		
1.056	@ 22°	0.005 - 15°	0.00033 - [illegible]

Copy of Mr H. P. Brown's notes of the experiments on the 5th Dec.

Calf No. 1. weighing 124½ lbs. was found to have an electrical resistance of 3200 ohms. A sponge-covered disc electrode 2" in diameter was applied to the forehead between the eyes, the hair being first clipped. The second electrode was made of wire netting 4" long and 2" wide covered with sponge and applied to the left of the spine back of shoulders. The sponges were saturated with a solution of Zn SO4 having a density of 1.054 at 60°F

A Siemens alternating current dynamo was used, its fields being changed from a standard Edison dynamo, and its EMF regulated by variable res. in the field circuit.

In the first experiment the main current was passed through the low resistance coil of a large converter made by an electric light co. and the calf was placed in the circuit of the high resistance coil for 30 sec. Before closing the circuit at 3.50 pm, on the subject the Cardew voltmeter showed 1100 volts in the secondary but as soon as closed the potential at once fell to 100 volts and remained stationary. The animal dropped but was uninjured as it rose to its feet 9 min. later.

The converter was then disconnected and the main current at 770 volts was applied for 8 seconds. Death was instantaneous. The animal was at once dissected by Drs Bleyer and Ingram. In the brain the vessels were found filled with blood but there were no hemorrhages. The brain remained very warm even after being exposed for few minutes to the air and immersed in cold water. The heart and lungs were found to be perfectly normal. The hair on the forehead projected beyond the sponges and touched the metal plate of the electrode and was scorched, but the skin was uninjured.

The second calf weighed 145 lbs and had an electrical resistance of 1300 ω between the electrodes which were placed as before, the metal of the disks being further protected by wrapping the edge with cotton waste. At 4.26 pm the alternating current at 750 volts was applied for five seconds. Death was instantaneous and the heart action ceased at once but reflex movements upon excitation were observed for 1½ mins.

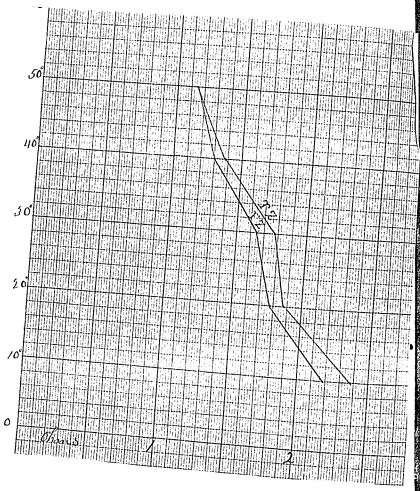
The calves were purchased from a butcher and were in good condition. The meat was pronounced fit for food, the fact being certified by him in writing.

A horse weighing 1230 lbs with halter was the next subject. His hip was dislocated but otherwise he was in good condition. Connection was made by wrapping cotton waste saturated in water round each fore leg and holding in place with bare copper wire. It was suggested by the physicians present that with this connection the current would pass through the muscles of the chest and not reach the spine or heart. This proved to be the case. The resistance was found to be

11,000 ohms. It was attempted to pass an alternating current of 1200 volts through the animal for a fraction of a second by closing the circuit with the rapid blow of a hammer on a metal plate but in preparing for the experiment the Cardew voltmeter was disabled. A file of lamps was then substituted and the EMF calculated. The current from the dynamo was passed through the converter above mentioned but with unsatisfactory results in obtaining the desired EMF in the secondary circuit. A ring converter was then tried and abandoned. A smaller ring converter was then substituted and the field circuit resistance adjusted until the a series of 18 lamps of the Edison type were brought up to redness in the secondary circuit. The current was then applied by a single tap from the hammer at 5.20pm but the animal was uninjured. The converter which was deemed of insufficient capacity for the purpose was abandoned and the dynamo circuit used. A series of 7 lamps was connected to the primary wire and brought up to redness. At 5.25pm contact with the horse was made for 5 seconds but the animal was uninjured. At 5.27 the same current was applied for 15 seconds with no apparent injury. The file of 7 lamps was then brought up to bright incandescence and the current was applied for 25 seconds at 5.28pm. during which time the water in the cotton waste steamed. The result was fatal.

These experiments proved the head and spinal column to be the best points of application of the current for the purpose and disposed of the suggestion to need wrettets as electrodes.

Those present were Eldridge T Gerry. Professors R. Ogden Doremus, Chas. A. Doremus, Dr Frederick Peterson. Dr Frank A. Ingram. Dr J Mount Bleyer. M. Bourgonon, Mr John Murray Mitchell Mr Galvin, and Mr Thos A Edison Mr A. E. Kennelly, and Harold P. Brown.



6 .25 light bottles were made up as follows

LVIII New cast zinc electrolytically pure not amalgamated but cleaned with sandpaper in heated (boiled) $Zn SO_4$ c.c. metre solution.

LIX New cast zinc 5% alloy, not amalgamated but cleaned with sand paper in boiled $Zn SO_4$ c.c. metre solution.

LX New cast zinc electrolytically pure amalgamated hot and in boiled $Zn SO_4$ c.c. metre solution

LXI New cast zinc 5% alloy) amalgamated hot and in boiled $Zn SO_4$ c.c. metre solution.

{LXIII, LXIV} New cast zinc 5% alloy) amalgamated hot and in boiled $Zn SO_4$ c.c. metre solution. Varnished on backs and sides.

LXII New cast pure zinc amalgamated hot and in boiled $Zn SO_4$ c.c. metre solution. Varnished on backs and sides.

The plates were heated by boiling them in water, and then amalgamating them in cool mercury.

The solutions were all cool before immersing the zincs in them.

December 6th Friday.

Took a temperature series on bottles #s LXIII and LXIV. by immersing them in water to the lids, contained in a large copper vessel and maintaining the temperature for a long time to allow uniformity. The current was kept flowing through them.

Bottle	Bridge	Mag. thro bottle	Temp: of bottles	Res: std	Lead	Res of bottle	Av. res. of each bottle Ex	Av. res. of each bottle Ex	
LXII	1000/0	10	19°	5.60	0.25	5.35	2.68	2.68	
LXIV	21°C		50°	2.55		2.30	1.15	1.15	
in series			40°	2.85 f2 3.00 f2		2.60 2.75	1.38	1.30	
			30°	3.79 f2 3.54 f2		3.55 3.39	1.78	1.65	
			21°	4.00 f2 3.80 f2		3.75 3.55	1.88	1.78	
			10°	5.00 f2 4.60 f2		4.75 4.35	2.38	2.18	

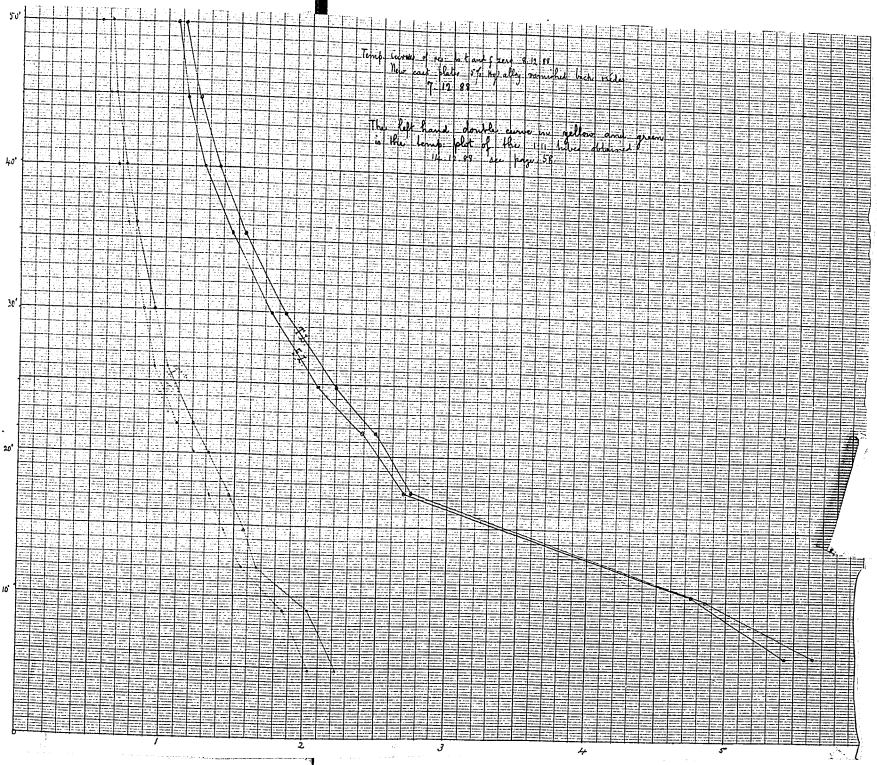
The plot of these observations with temperature as ordinate and resistance as abscissa is shown on the curve sheet opposite.

The irregularity of the curve, particularly at 30°C is presumably due to the non coincidence of the temperature inside the sealed bottle with that outside in the heated liquid.

To overcome this source of error :—

December 7th Saturday.

The plates were taken out of these bottles and immediately amalgamated without heating them. They were then replaced and the lids left off so that the two standard thermometers could be immersed directly in the bottles, joined up in series. They were first placed in icewater till the temp: had fallen to 5°C and then they were allowed to rise in air to the normal, afterwards they were heated to 50°C steadily in water over a burner.


Temp. curves of 10 in tank of sea 6.12.88
The case plate is typically recorded back inside
7.12.88
The left hand double curve in yellow and green is the temp. plot of the 11th tube obtained 11.12.88 see page 58.
50°
40°
30°
20°
10°
1
2
3
4
5

December 7th Saturday) contd:—

The following readings were then obtained, the plot is given opposite

Ref. No.	Bridge	Current thro bottle	Temp. Bridge	Temp. bottle EXP	Temp. bottle CED	mean temp	Res. dect	lead	Amp. bottle	Average Res. L F2.	average Res. L F2	
1	1000/0 Gravity cell	10 mas	25°C	6·0°	6·0°	6·0°	11·50 T 11·10 F	0·25	11·25 10·85	5·63	5·43	
2			10·1°	10·2°	10·25°		9·95 F 9·55 F		9·70 9·30	4·85	4·65	
3			17·2	17·6	17·4		5·7 F 5·4 F		5·65 5·35	2·73	2·68	
4			21·6	21·6	21·6		5·2 F 5·0 F		4·95 4·75	2·48	2·38	
5			25	24·6	24·8		4·60 F 4·40 F		4·40 4·15	2·20	2·08	
6			29·8	29·9	29·9		3·85 F 3·75 F		3·70 3·50	1·85	1·75	
7			35·5	35·0	35·2		3·35 F 3·17 F		3·10 2·92	1·55	1·46	
8			40·2	40·0	40·1		2·95 F 2·79 F		2·73 2·53	1·37	1·27	
9			44·9	44·6	44·8		2·70 F 2·55 F		2·55 2·30	1·23	1·15	
10			50·7	50·2	50·5		2·51 F 2·40 F		2·26 2·15	1·13 ~~2·05~~	1·08	

The res: at 22·9°C of the spools and wire between the copper clips of Bergmann's new special meter with the T.B. 25°C = 1000/0

Repeated this test on the 9th Dec: and both equal (about 17·78ω). above discrepancy probably slight

Left hand 18·662 = 19·38ω Right hand 19·042 = 17·78ω

The following hypothesis is now under consideration by evidence. To account for the improved behaviour of the plates in the meter bottle after amalgamating the plates hot and heating the solution.

Under ordinary conditions as met with in present practice, the zinc plates in the presence of mercury and water forms $Zn(HO)_2$ taking the oxygen either from gas occluded under the amalgamated surface or from dissolved oxygen in the solution and the hydrogen from such traces of acid as may be in solution or from the water the reaction being

$$2Zn + 2(H_2O) + O_2 = 2\{Zn(HO)_2\}$$

When however this salt which is more or less insoluble is not formed owing to the absence of the necessary oxygen by driving off the dissolved solution gas, and the occluded gases in the metal then the following reaction slowly goes on between the zinc and the $ZnSO_4$ in the presence of water

$$Zn + 2H_2O + ZnSO_4 = ZnSO_4 \cdot Zn(OH)_2 + H_2$$

The basic sulphate here formed should have a slightly alkaline reaction. It is said to be soluble in small quantities. Hydrogen would be evolved.

It remains to be seen whether the gas that forms on the plate surface is really hydrogen, and whether the same reaction can be obtained with pure zinc without the presence of mercury.

Constant of no 2 (smaller) A+S Engine in Dynamo room. Rect 1½ (13×12)

Front constant $\frac{(132.73 - 2.23) \times 1}{33,000} = 0.0039$

Back constant $\frac{132.73 \times 1}{33,000} = 0.004402$

Meter Experiment contd.

Sunday 9th December.

No. of plate	No. of plate	Meter	Mean Temp. of meter	Average Load	Weight susp.	Sum of weights	Joint stat weights	Weight susp. 28.11.88	Loss	Gain	
I	1	Exp. Std.	18°	3.8 amp.	88.5230	176.3933	176.3950	86.9887	0.4657		
	2				87.8703			87.3990		0.4713	
II	3	Std. #1	21°		88.5276	179.1781	179.1810	89.0018	0.4742		
	4				90.6505			90.1742		0.4763	
III	5	Std. #2	21°		88.8066	173.6221	173.6260	89.2789	0.4753		
	6				84.8155			84.3411		0.4774	
1	1	Gold meter	4°		79.850			79.310	0.460		
1a	1a				75.998			76.400	0.402		
2	2	Warm meter	25.6°		82.146			82.625	0.429		
2a	2a				79.556			80.010	0.456		
3	3	None			82.100			82.1295		0.030	
3a	3a				77.828			77.815		0.013	

			Date of preparation	Days intervene	Loss corrected for error of meter	Gain add for error of meter	Mean Std Loss.	Ratio of stat. to Std loss.	Error.	Gain by oxidation.
I	1	Exp. Std.	28.11.88	11	0.4739	0.4707		1.0040	+0.4%	
	2					0.4795				0.0056
II	3	Std. #1	"	11	0.4768		0.4756	0.9974	−0.26%	
	4					0.4789		1.0012	+0.12%	0.0021
III	5	Std. #2	"	11	0.4762					
	6					0.4784				0.0022
1	1	Gold meter	4°	27.11.88	12	0.460		0.967	9.4%	
1a	1a					0.402		0.845		
2	2	Warm meter	25.6°	"	12	0.429		0.902	7.0%	
2a	2a					0.456		0.959		
3	3	None		"	13					0.030
3a	3a									0.013

Monday 10th December.

Made up 3 bottles as follow

XV } Zincs of Benmanix ordinary pattern twice in use, amalgamated
XVI } when hot after boiling water with mercury itself new
XVII } boiling temp. of water. solution 1.0514 heated separately to boiling.

No. of bottle	No. of plate	Meter	Mean temp.	Av. load	Weight susp.	Sum of pairs	Joint stat weights (between)				
XV	1	Std. #2		10 amp	87.1247	173.8620	173.8646				
	2				86.7373						
XVI	3	Gold special			90.9108	175.4392	176.4335				
	4				85.5284						
XVII	5	Gold special			86.0237	172.0794	172.0787				
	6				86.0557						

These bottles were intended for a companion of the special meter with the standard #2. The special meter was set in the refrigerator in place of commercial 25 meter #1. They commenced work at 9.0 am on the 11th at 10 amperes of current.

Meter Experiments contd —

December 10th Monday

Made up two narrow bottles out of glass tube cut and closed so as to just hold the connected plates. The height of the bottles so formed was 13.4 on the inside and the diameter 3.5 They were corked and labelled nos. XLVIII and XLIX. The plates were amalgamated hot and the liquid was boiled.

December 11th Tuesday.

Meter experiments contd.

Took down bottles LXIII and LXIV and reamalgamated the plates hot Boiled some 1.111 solution and inserted the plates after cooling.

Refilled them Nos LXX and LXXI.

The resistance of these on the 11th Dec. with 1 ampere @ 21.2°C = {2.92 / 2.94} + {3.19 / 3.22} respectively.

December 12th Wednesday.

Different trials made of solutions &c.

The following decisions were come to in conference with Mr Witt on the details of the proposed new Edison meter subject to the approval of the Standardizing Bureau

1st That the resistances of the bottles and the data connected with them should be expressed in legal unit.

2nd That the shunt resistances should be doubled.

3rd That the resistance of the bottle should be approximately 2 ω @ 60°F or 15.5°C

4th That the plates should be varnished on their backs and rims

5th That the resistance should be so arranged in the bottle circuit as not only to compensate for temperature but also to give 1 milliampere for each ampere hour of current.

6th That the bottles should be reduced in dimensions so as to just fit the plates.

7th That the foot at the base connection should be reduced to about ¼".

8th That the density of solution should be increased to about 1.11 or to such a value that the res. of the bottle should be 2.0 ω @ 15.5°C.

9th That no larger plates should be employed than the 25th plate and that all alterations for larger meters would take place with the aid of the shunt.

December. 13th Thursday.

A test was made of a leaden plate battery forming a primary cell with chemical excitants but having all the appearance of a secondary cell. The plates are 9 in number on each grid 30 high 15.5 broad 0.3 thick and the grids slide into each other vertically in such a manner that the interspace between the opposite faces is 0.25 cm. The total area on each plate is about 450 × 2 = 900 and on each grid effectively about 7200

These grids were immersed overnight in separate solutions and then coupled in one of these solutions for work.

An E.M.F. of about 2 volts and a capacity of 25 Ampère hours was claimed for them by their inventor Mr Jenkin The cell was set to work upon a measured 0.5 of platinoid.

December 13th Thursday. Reading battery test.

Hours	Time	Hours at work	EMF	P.D.	C.	I.R.	Watts	Mean EMF	Joules.	Joules up to present	Ave. Watts for hour
1	9.00	0.00	1.940	1.924	3.848	0.0042					
2	9.15	.15	1.924	1.910	3.820	0.0037	7.407	1.932	6670	6670	
3	9.30	.30	1.908	1.892	3.784	0.0042	7.285	1.916	6560	13230	
4	10.00	1.00	1.884	1.864	3.728	0.0053	7.121	1.896	12820	26050	
5	10.30	1.30	1.890	1.866	3.732	0.0064	7.038	1.887	12670	38720	
6	11.00	2.00	1.768	1.730	3.460	0.0110	6.577	1.829	12040	50760	
7	11.30	2.30	1.405	1.274	2.548	0.052	4.770	1.588	7590	58350	
8	12.00	3.00	1.804	0.982	1.886	0.100	2.709	1.245	4886	63230	
9	13.00	4.00	0.328	0.222	0.444	0.240	0.792	0.705	2850	66080	2.6
									66080		

3.7 amperes may be said to have been delivered for 2 hours and the total capacity cannot exceed 10-ampere hours.
A curve sheet was made out and preserved.

Tested the Transformer armature as follows:—
Resistance of bare wire ring between opposite points 0.17 ω
" " Fine " " " " 4.69 ω
" between the circuits = Practically infinite.

To ascertain whether the resistance of platinoid was liable to sensible variation when heated by current for a long time, measured a strip as follows—
3 Daniells gravitis working thro' 0.1 Legal-Ohm + the 0.1 strip whose ends were soldered into two st meter clips

No. of obs	Deflection no strip	Deflection on strip	Diff	Mean Ratio	Legal Ohm @ 22.5°	Mean Res. of strip	v	v^2	$0.6745\sqrt{\frac{\Sigma v^2}{n(n-1)}}$	Res. of strip @ 22.5°	
1	626.5	624.9	1.6	0.997444	0.10011	0.09984	-3×10^{-5}	9×10^{-10}	0.1508	0.09998	
2	628.0	626.5	1.5	0.99761		0.09987	-1×10^{-5}	1	$\times 8.9\times10^{-5}$	± 0.00009	
3	627.7	626.7	1.0	0.998841		0.09995	$+7\times10^{-5}$	49	$=0.1342$		
4	629.5	628.2	1.3	0.99793		0.09990	$+2\times10^{-5}$	4	$\times10^{-5}$		
5	630.7	629.0	1.7	0.99730		0.09984	-4×10^{-5}	16			
	22.7	25.3						$\Sigma v^2 = 79\times10^{-10}$			
Mean	628.5	627.1	1.4	0.99777		0.09989					

This strip was put in cct: with the carpenter's shop motor.

Measured the resistance of two pairs of 25 lt plates as follows:—
Two 25 lt bottles were used
A had 1.054 solution
B " 1.110 "
Two 25 lt tubs were used 3.7 cms drain
C had 1.054 solution 12.4 " deep
D " 1.110 "
Couple 1 was formed of plain freshly amalgamated plates
" 2 " " " cast 5% plate " and varnished on the backs sides with 2 coats of Japan.
To lower the resistance a current of about ½ ampere was sent through these couples in solution for about an hour beforehand.

Couple #1

Obs.	Res. in A 1.054 bottle	Res. in B 1.111 bottle	Res. in C. 1.15 tube	Res. in D. 1.111 tube	Change
1				{1.02 / 0.97}	
2		{0.96 / 0.94}			{−0.06 / −0.03}
3	{2.85 / 2.30}			{1.89 / 1.36}	
4			{2.42 / 2.37}	{+0.47 / +0.01}	
5		{1.03 / 1.01}		{−1.39 / −1.36}	
6				{1.20 / 1.18}	{+0.17 / +0.17}
7		{1.20 / 1.19}			{−0.0 / +0.01}
8				{1.32 / 1.20}	{+0.12 / +0.11}
9					
10					

Couple #2

Obs	Res. in A 1.054 bottle	Res. in B. 1.111 bottle	Res. in C. 1.15 tube	Res. in D. 1.111 tube	Change
1				{1.09 / 1.06}	
2		{1.19 / 1.15}			{+0.11 / +0.09}
3	{1.99 / 1.95}				{+0.80 / +0.80}
4			{1.93 / 1.85}		{−0.06 / −0.10}
5		{1.01 / 0.98}			{−0.92 / −0.87}
6				{1.02 / 0.99}	{+0.01 / +0.01}
7		{1.02 / 0.99}			{0.00 / 0.00}
8				{1.02 / 0.99}	{0.00 / 0.00}
9			{2.05 / 1.93}		{+1.03 / 0.94}
10	{2.05 / 1.93}				{0.00 / 0.00}

The temp: of the solutions was about 18°.6 c.

The effect therefore of changing a plain couple from bottle to tube was

for 1.054 solution . {0.07 / 0.03}

" 1.111 " {0.07 / 0.03}

with a varnished couple

for 1.054 solution 0.

" 1.111 " 0.

The upper value in the bracket is for t.z the lower for f.z.

The res: of no 1. in 1.054 tube was {2.42 / 2.37} in 1.11 tube {1.18 / 1.15}

" " " " 2 " 1.054 " " {1.89 / 1.59} " 1.11 tube {1.40 / 1.03}

The res: of the tube seems to fall therefore about 50%.

Observations by Mr Watt upon polarization.

The current was kept steadily on one bottle for the times indicated and readings taken to true and false zero.

No. of Obs	Time	Current on for	R. to T.Z.	R. to F.Z.	Current this bottle	Diff	Temp bottle	ε volt	ε mean
1	9·30	0·0	–	–	1 mamp		25°		
2	·50	0·20	1·18	1·60	–	0·38	23·8°	0·0082	0·00032
3	11·10	0·40	1·20	1·75	–	0·55	23·5°	0·00055	0·00055
4	·15	0·05	1·27	1·37	5	0·16	23·5°	0·0008	0·00016
5	·20	0·05	1·22	1·34	10	0·12	23·5°	0·0012	0·00012
6	·35	0·15	1·33	1·43	15	0·10	23·2°	0·0023	0·00015
7	·40	0·10	1·42	1·53	20	0·11	23°	0·0022	0·00011
8	·50	0·20	1·47	1·60	20	0·13	23·4°	0·0026	0·00013
9	·55	0·03	1·48	1·63	15	0·15	–	0·0023	0·00015
10	·56	0·03	1·49	1·67	10	0·18	–	0·0018	0·00018
11	12·00	0·04	1·49	1·76	·5	0·27	–	0·0014	0·00028

Calculation of the resistance to be put in the bottle circuit of a 25 lt. new Edison meter including the bottle itself.

The Legal ampère liberates 0.00001086 grammes of H. per sec.
Taking the atomic weight of zinc in Watts dictionary 64.90 the corresponding mass of metal disengaged = 0.00033370
Taking the figure in Anthony & Brackett's Physics 65.88 we have
0.00033369 — 65.33
Taking Ayrton's number of
0.00033293

Assuming the number 0.00033370 in the absence of more certain information, we have in one hour

$0.000337 \times 3600 = 3.37 \times 10^{-4} \times 3.6 \times 10^{3} = 12.132 \times 10^{-1} = 1.2132$ grammes.

Consequently the circuit that takes 1 milligramme per hour must have a resistance of $\frac{4}{1.2132 \cdot 2}$ so that in circuit with
0.01 ω we should have a bottle + spool of 12.122 ω
0.02 ω . . . . . 24.2644 ω

In such a circuit, a variation due to bottle changes
of 1 ω produce an error of 4.12 %
" 2 ω " " " " 7.63
" 3 ω " " " " 11.0 %
" 4 ω " " " " 14.2 %
" 5 ω " " " " 17.1 %

The discrepancy between Ayrton's value + Watts value is about 0.7 %.

December 14th Friday.

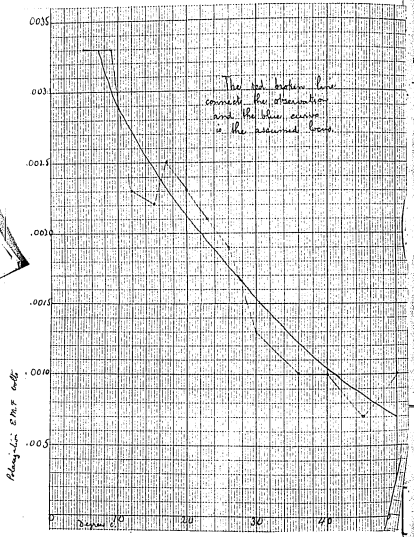
10.0 Metts test stopped, and bottles removed. The bottles in the standard meter was in good condition but those in the special meter placed in the refrigerator were much 'smutted.' No ☐XVII was in fact nearly if not quite bridged over. The resistances of the three bottles just after removal were :-

☐XV in standard meter warm 1.34 to 1.14 f.z.
☐XVI " special " cold 2.44 to 1.49 f.z. av. temp 8°C.
☐XVII " special " " 0.74 " 0.64 f.z.

The plates were then dried and weighed as follows:-

No. of roll	No. of plate	Meter	Mean Temp	Weight wet	Sum	Joint weight	Weight dry at 16° Fah.	Loss	Gain	Discrepancy
☐XV	1	Std. ☐22	22.6	~~87.8349~~	~~173.8629~~	~~173.8629~~	87.1247	~~2.0325~~	~~0.7102~~ ~~0.6255~~	
	2			86.0280			86.7373	~~2.7203~~	~~2.7203~~ ~~0.6017~~	
							173.8646	0.7113		
								0.6017		
☐XVI	3	Special	8°	~~91.4275~~	~~176.2543~~	~~176.2543~~	90.9108	~~1.5581~~	0.5067	
	4			~~84.8268~~			85.5304	0.8836	0.7306	— 3.9 %
							176.4335	0.1780		
☐XVII	5	Special	8°	~~85.3560~~	~~171.5739~~	~~171.5739~~	86.0237	0.6677		Short circuited.
	6			~~86.5619~~			86.0557	~~2.6280~~	0.4613	
							172.0794	0.2027		

The test has been running for 3 days at about 18 hours a day = 54 hours at 10 ampères = 540 ampère hours = 0.6648 transfer.



Meter tests cont:—

Took the resistance of 3 twice bottles Nos [XXII] [XXIII] and [XXIV] made up on the previous day with cast 5% zinc japanned, and 1.111 solution.

at noon. the three in series with 20 m. amps. @ 20.8 °C = $\begin{cases} f_1 .15\ t_2 = 1.38\ \text{cell} \\ f_3 .22\ f_2 \quad 1.27 \end{cases}$

The current was left on till

13. 10 the res. was then - - - - @ 20.2° C = $\begin{cases} f_1 .09\ t_2 = 1.63\ \text{cell} \\ f_4 .44\ f_2 \quad 1.48 \end{cases}$

Tested each separately @follows [XXV] 2.48 t_2, 2.28 f_2.

[XXVI] 1.24 t_2, 1.15 f_2

[XXVII] 1.09 t_2, 1.02 f_2. Total = $\begin{cases} 4.81\ t_2 \\ 4.45\ f_2 \end{cases}$

Selected the two last for a temperature test joined up in series and neglected [XXII] as it seemed unduly high.

Test No.	Time hrs bottle	Res. L.T.2. twice bottle	Res. L.T.1. twice bottle	Res. per bottle t.2.	Res. per bottle f.2.	temp bottle	diff between t.2. & f.2.	e.m.f. of polarization	emf per bottle		
1	20	4.39	4.06	2.20	2.03	4.8°	0.33	0.0066	0.0033		
2	"	4.07	3.74	2.04	1.87	9.0°	0.33	0.0066	0.0033		
3	-	3.34	3.11	1.67	1.56	12.2°	0.23	0.0046	0.0023		
4	-	3.08	2.86	1.54	1.43	14.6°	0.22	0.0044	0.0022		
5	-	2.91	2.66	1.46	1.33	17.°	0.25	0.0050	0.0025		
6	-	2.64	2.41	1.32	1.21	20.°	0.23	0.0046	0.0023		
7	-	2.39	2.18	1.20	1.09	23.°	0.21	0.0042	0.0021		
8	-	2.07	1.88	1.04	0.94	26.°	0.19	0.0038	0.0019		
9	-	1.86	1.73	0.93	0.87	30.°	0.13	0.0026	0.0013		
10	-	1.60	1.50	0.80	0.75	36.5°	0.10	0.0020	0.0010		
11	-	1.46	1.36	0.73	0.68	40.°	0.10	0.0020	0.0010		
12	-	1.31	1.26	0.66	0.62	45.°	0.07	0.0014	0.0007		
13	-	1.23	1.13	0.62	0.57	50.°	0.10	0.0020	0.0010		

Recommenced meter test.

Made up bottles Nos. [XXVI] [XXVII] [XXVIII] with 1.054 solution and the same plates as in the last test reamalgamated hot, but the solution were not heated afresh. Bottle No [XXII] was set in the standard #2, but bottles nos [XXIII] and [XXIV] were placed in the special meter and over the steam pipes. Two other bottles [XXXII] and [XXXIII] were made up with plain amalgamated plates unweighed — one in 1.054 solution, the other in 1.11 solution and both left in a commercial 25 lt meter in the refrigerator.

Bottle No.	Plate No.	Meter	Temp.	Load	Weight weight	Sum.	Weight of pair	Time of start		
	1			10 amp	85.0922	169.0092	169.0102	18 o'clock		
	2				84.0170			11.6.12.88'		
	3				89.7527	176.0637	176.0642			
	4				86.3110					
	5				84.7892	168.1569	168.1578			
	6				83.3677					

To ascertain how far the emitting of plates was affected by the density of the solution, made up four 25 lt. bottles nos. ⊏XXVIII. ⊏XXIX. ⊏XXX. and ⊏XXXI. The peroxides were all prepared cast zincs % of 5% freshly amalgamated after heating. The solutions were not boiled but their densities were as follows:—

No.	⊏XXVIII	1.026	@ 20°C
"	⊏XXIX	1.059	"
"	⊏XXX	1.124	"
"	⊏XXXI	1.200	"

These bottles were joined in series with the gravity battery and ran from at 21 o'clock, the current being 20 milliamperes.

Reading No.	Time	Hours at work	E.M.F.	P.D. across	C.	J.R.	Watts.	Mean EMF	Joules	Joules up to period	Ave Watts for 7 hrs
1	10.45	0.00	1.916	1.904	1.904	0.006	3.648				
2	11.00	0.15	1.899	1.887	1.887	0.006	3.583	1.896	3250	3250	
3	11.15	0.30	1.893	1.873	1.873	0.011	3.525	1.880	3200	6450	
4	11.45	1.00	1.883	1.863	1.863	0.011	3.507	1.868	6340	12790	
5	13.15	2.30	1.754	1.710	1.710	0.025	2.999	1.787	17500	30290	
6	13.45	3.00	1.590	1.499	1.499	0.083	2.393	1.605	4860	35150	
7	14.15	3.30	1.380	1.264	1.264	0.091	1.744	1.383	3670	38820	
8	14.45	4.00	1.154	1.023	1.023	0.128	1.180	1.144	2970	41790	
9	15.15	4.30	1.073	0.914	0.914	0.175	0.980	0.969	2070	43860	
10	15.45	5.00	0.960	0.754	0.754	0.273	0.723	0.884	1620	45480	
11	16.15	5.30	0.879	0.623	0.623	0.410	0.547	0.689	1220	46700	
12	16.45	6.00	0.813	0.520	0.520	0.560	0.422	0.572	860	47560	
13	17.15	6.30	0.743	0.450	0.450	0.650	0.334	0.485	650	48210	
14	17.45	7.00	0.678	0.386	0.386	0.750	0.261	0.418	540	48750	1.93
								Total	48750		

The above table shows the results of a second trial of Jamieson's leaden cell after recharging) during the night. The cell was worked on this occasion through to. The work done was 49000 joules in 7 hours against 66000 in 10 hours on the first occasion.

December 15th (Saturday).

At 8 am there was distinct emitting on the − plate of tube no ⊏XXX 1.124 and very slight emitting on that of ⊏XXVIII 1.026. The other plate tube showed no emitting but gave off gas in bottle. Increased current to 50 milliamperes.

Now increased current to 100 milliamperes.

20 o'clock " " " 200 milliamperes.

The same results followed these currents, 1.026 emitted heavily, 1.124 a good deal and the other not visibly.

December 15th Saturday

Following measurement made of the energy consumed and utilized by the Carpenter's shop Motor which is a No. 4 Edison Dynamo.

No. of Test	Speed	Machine driven	Current	Volts	Watts	H.P.	Machine	HP needed	Sum of amps used outside
1	2000	1	29	112	3248	4.33			
2		12	37		4144	5.52	(a) Circular saw	1.19	
3		123	41		4592	6.12	(b) fig saw	0.60	
4		1234	65		7280	9.98	(a) Planer	3.89	
5		12345	67		7504	10.0	(c) lathe	0.29	
6		123456	95		10640	14.19	(d) boring machine	4.19	
7		1	32		3680	4.77			
8		12	39		4370	5.85	(a) Circular saw	1.08	
9		1	31		3470	4.63			
10		13	38		4240	5.68	(b) fig saw	1.05	
11		1	31.5		3520	4.69			
12		14	48		5380	7.17	(a) planer	2.48	
13		1	31		3470	4.63			
14		15	36.5		4090	5.45	(c) lathe	0.82	
15		1	31		3470	4.63			
16		16	33		3700	4.93	(e) borer	0.20	
17		1	29		3250	4.33			
18		17	41.5		4650	6.20	(f) moulder	1.87	7.50

(a) = shaping (b) = fig saw (c) = lathe (f) = moulding machine
(e) = circular saw (d) = planer (d) = boring machine

The average HP absorbed may therefore be taken as 8 or fully 50 amperes.

December 16th

at noon the emitting experiment was stopped and the bottles examined. The plates were subsequently scraped and replaced without further interference. The emitting was very light and muddy in 1.026 and became harder in each successive density. The quantity was greatest in 1.026 filling almost the entire interspace. It was next most plentiful in 1.124 next in 1.059 and least in 1.201 comparatively little in this last case.

The plates were replaced in the same bottles and raised in them to 100°C. The bottles while still warm were joined up in series and the current of 200 milliamperes started in the opposite direction so that the plate which had been gaining now lost.

The experiment lasted for 40 hours, at the conclusion of which period the current was interrupted.

On examination (18th Dec), the 1.026 had little or comparatively little emitting, the 1.059 was full of smut between the plates the 1.124 formed a gradient like the black triangle between the plates and the 1.20 had a little less. So that the order of quantity in emitting was 1.059 1.124 1.20 and 1.026. Examined the smut microscopically and found it partly composed of fine metallic particles.

Bottle No XI-VII which has been allowed to generate gas under solution in a sealed bottle for 18 days since the 29th ult was examined on the 17th December. The gas was carefully collected in a test tube and amounted to about 14 c.c. It was divided into two parts and each after mixing with atmospheric air gave the characteristic hydrogen pop on applying flame. The solution was distinctly acid. 90% of this hydrogen should be produced by the decomposition of the free H_2SO_4 in solution by zinc then the amount of zinc dissolved to produce 30 c.c. in one month of H^2 would be 50 milligrammes.

Motor Experiments contd:—

6th December 1911 Tuesday

Motor test interrupted. Took down bottle, weighed plates as follows.

No. of bott.	No. of plate	Motor	Mean temp	When started	Weight empty	Sum.	Joint weight	Weight in air	Loss	Gain
LXXXI	1	Std #2	26·5	18 11 12.55	84·6815	169·1178	169·1195	85·0922		0·4407
	2				84·4663			84·0170	0·4493	
LXXII	3	Special			89·3116	176·0759	176·0767	89·7527	0·4411	
	4				86·7643			86·3110		0·4633
LXXIII	5	Special			84·3337	168·1672	176·1680	84·7892	0·4555	
	6				83·8335			83·3677		0·4658

	Loss cell for short circ	Error of Special meter	Gain in Gain by Calculation	Load		
In this experiment no smutting was observable. But of the two bottles set in a commercial meter in refrigerator # LXXXI and LXXXII one with 1·05% and the other with 1·11 solution the denser solution bottle showed some smutting.	0·4502		0·0083			
	0·4411	0·9799 = 2%	0·0125	10 ampères		
	0·4483	0·9958 = 0·4%				
	0·4555	1·0120 = 1·2%	0·0102			

To ascertain whether the cast zinc had any less density than the rolled zinc, took one of Bergmann's zincs, two of our cast 5% zincs and one cast freshly today from Bergmann's zinc melter up for the purpose.

No.	Quality	Amalgam	alloy Hg	Weight in air	Weight in water	Difference	Sp. g.			
1	new Bergmann bottle	new	0%	104·0141	89·375	14·666	7·094			
2	Laboratory cast	new	0%	83·719	71·920	11·799	7·095			
3	Bergmann bottle	new	0%	81·890	70·245	11·645	7·032			
4	Bergmann spiral wound new	new	0%	114·363	98·473	15·890	7·197			

To test the effect of acidity of solution on the resistance and on the smutting took some s.p. dense $ZnSO_4$ solution and reduced it neutral by the addition of $Zn(HO)_2$. Took some of the same original solution and left it with the original distinct acid reaction but of same density as the neutral. 2 Bottles 84 and 85 were made up with the neutralized solution 1·075 sp.g., bottles 86 and 87 were prepared with the acid solution 1·075 sp.g. all four heated to boiling point, and fitted with Bergmann zincs amalgamated hot with hot mercury. 84 and 86 were started with 78 79. 80 and 81 in a smutting test at 16 o'clock with 200 milliampères. The four bottles had their solutions filtered and heated with the zincs filed and amalgamated. Bottles 85 and 87 were set aside.

$$78{\cdot}21\,(1+x)^{16{\cdot}6} = 83{\cdot}20$$
$$(1+x)^{16{\cdot}6} = \frac{83{\cdot}20}{78{\cdot}21} = 1{\cdot}064$$
$$1+x = \log^{-1}\left(\frac{0{\cdot}0269446}{16{\cdot}6}\right)$$
$$= \log^{-1} 0{\cdot}0016229$$
$$= 1{\cdot}00376$$

$$83{\cdot}2\,(1+x)^{66{\cdot}2} = 99{\cdot}85$$
$$(1+x)^{66{\cdot}2} = \frac{99{\cdot}85}{83{\cdot}2} = 1{\cdot}20012$$
$$1+x = \log^{-1}\left(\frac{0{\cdot}0793246}{66{\cdot}2}\right)$$
$$= 0{\cdot}0011967$$
$$= 1{\cdot}00276$$

$$78{\cdot}21\,(1+x)^{82{\cdot}8} = 99{\cdot}85$$
$$(1+x)^{82{\cdot}8} = \frac{99{\cdot}85}{78{\cdot}21} = 1{\cdot}2767$$
$$1+x = \log^{-1}\left(\frac{0{\cdot}1054889}{82{\cdot}8}\right)$$
$$= 0{\cdot}0012812$$
$$= 1{\cdot}00295$$

Boston, Dec 17, 1888.

Reels No.	13 Results Meter No. 305 One side 25 Dl. bottle + fluid Other " 100 Dl. " " " Deflection	Deflection	Resistance	13 Results All 100 Dl. bottles + fluids Resistance	A side	B side
1.	.250 gp	1.023 gp	1.120 gp	.885 gp	.805 gp	
2.	.303	1.150	1.212	.725	.710	
3.	.345	1.273	1.380	.595	.565	
4.	.358	1.410	1.432	.650	.605	
5.	.335	1.385	1.340	.595	.505	
6.	.343	1.363	1.372	.570	.590	
7.	.348	1.328	1.392	.570	.545	
8.	.374	1.388	1.500	.960	1.170	
9.	.305	1.213	1.232	.870	.890	
10.	.275	1.075	1.100	.945	.945	
11.	.235	.910	.957	1.040	1.030	
12.	.298	1.140	1.192	.450	.850	
13	.265	1.045	1.072	.615	.610	

13 Results Meter No. 306 One side 25 Dl. bottle + fluid Other " 100 Dl. " " " Deflection	Deflection	Resistance	13 Results All 100 Dl. bottles + fluids Resistance	A side	B side
.370 gp	1.093 gp	1.294 gp	1.075 gp	1.085 gp	
.323	1.273	1.292	.625	1.125	
.320	.948	.980	.895	.970	
.338	.865	1.332	.970	1.030	
.365	1.403	1.460	1.215	1.350	
.349	1.358	1.372	.940	.920	
.350	1.160	1.400	.770	.700	
.313	1.613	1.252	.960	.930	
.365	1.333	1.460	.850	.835	
.325	1.260	1.312	.715	.715	
.270	1.060	1.050	.630	.645	
.333	1.320	1.332	.650	.575	
.300	1.225	1.200	.410	.470	

(62)

(6) December 19th Wednesday

Meter Experiments contd:

Interrupted the meter bottle smuttering test that was commenced yesterday afternoon, at 15 o'clock, after 23 hours duration at 0.2 amp. On opening the bottles and examination there was slight evidence in favour of the supposition that the degree of smuttering diminished with the density and with the acidity of the solution, but not sufficiently marked, to warrant such a statement.

To measure the coeff. of temp. of copper, wound about 8 metres of fine silk covered copper wire diam: 0.002" = 0.004458 cm on an ebonite X spool and took its res: at three temperatures as follows:—

No. of Obs.	T.B.	Bridge	Res. of Std. coil for bridge	Temp. of Spool	Difference of Temp.	1+x	Coeff.	Best result	
1	25·2°C.	1000/10	83·20	24·6°C.					
2	25·4°C	-	78·21	7·2°C	16·6°	0·00376	0·376%	0·276%	
3	25·5°C	.	99·85	90·2°C.	66·2°	0·00276	0·276%		
					82·8°	0·00295	0·295%		

The results from the high temperature variation are not reliable owing to the variability of the temperature in the incubator.

The resistance of bottle [XXXVII] made up yesterday acid 1.750
[XXXVI] " " " neutral 1.850

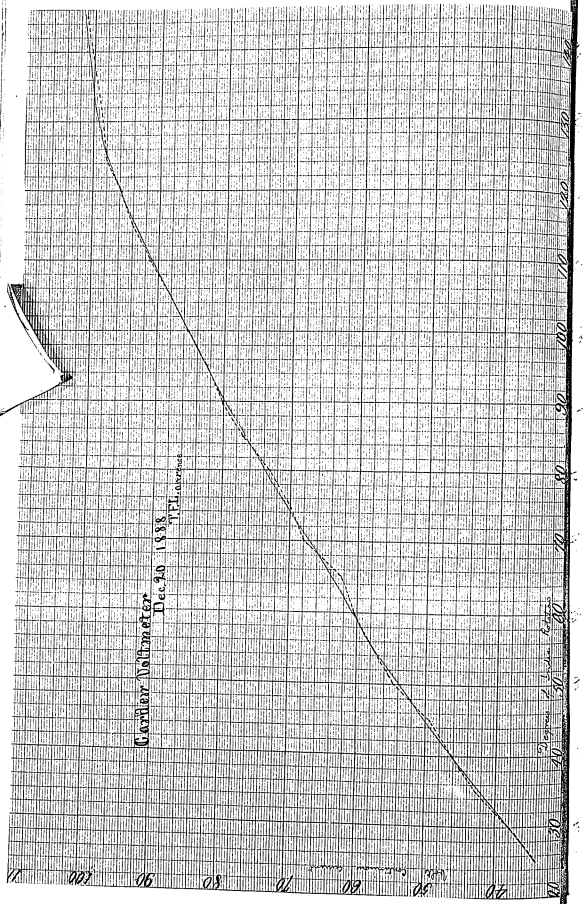
both [XXXVI] had leaked somewhat through a fresh crack but it was distinctly noticeable that the surface of the acid solution gives had bubbles on them while that of the neutral solution had none.

(7) December 20th Thursday.

For the measurement of the average resistance of different bottles wound 12 small spools of #26 B.W.G. G.S. wire and measured their res: by deflection method and comparison with the standard ohm at 24·6°C. Results as follows:— Res. of 1 = @ 24·6 = 1·0027 F.Z 275

No. of coil	Temp. of coil	Defl. on coil @ 24	Defl. on 1 = 24	Res. of coil @ 24·6°C	No. of coil	Temp.	Defl. on bot. @ 24	Defl. on 1 = 24	Res. of coil @ 24·6°C	
1.	24·6°	275 + 248	275 + 243·5	2·023	7	24·6°	275 + 245	275 + 243·5	2·012	
2		249·5	243·5	2·029	8		249	243·5	2·027	
3		248	243·5	2·023	9		248·7	243·5	2·026	
4		255·5	243·5	2·052	10		247·5	243·5	2·021	
5		236·5	243·5	1·978	11		248	243·5	2·023	
6		239·5	243·5	1·990	12		248	243·5	2·023	

On the opposite page appear some results given by Mr Edgar through Mr Wint relating to the behavior of 25 cl bottles in 100 cl meter.



Meter Experiment cont. –

December 20th. Thursday.

Finding that bottle #47 remained in good condition and that it gave off bubbles of gas on the zinc plate, prepared a solution to test its degree of acidity. Took 10 c.c. of Wilmotti's normal NaOH solution and diluted it with 90 c.c. of H_2O dest. thus making a 10% normal solution. Took 10 c.c. of the solution from # XLVII in a test tube and found that it ~~took~~ required the addition of some 35 drops of 10% N.S. to produce permanent turbidity.

Ordinary water solution seems to vary in acidity as prepared for our carboys. The lowest test that has been made is 5 drops of 10% N.S. to 10 cc. with permanent precipitate.

Set up four bottles # 92 93 94 and 95 for the purpose of measuring their resistance at a certain temperature.

No. 92 had plain zinc amalgamated but in boiled solution + 5 drops 10% N.S. P.P.
- 93 - - - - - - - - - - - with 2 drops of H_2SO_4 added
- 94 - - - - - - - - - - -

Bottle No.	Plate No.	Plate	Amalgamated	Solution	Acidity	Current & date of performance	Shunted by	Weight empty	Joint weight	Difference
92	1	Plain unamalgamated Zinc	In mercury heating under boiling water after being thoroughly washed in boiling water	Repeat over and with fresh joint	5 drops N.S. R.P.	0.01 amp	—	87.2212	167.9210	+0.0006
	2							80.6992		
93	3				do. + 2 drops N/R	21.12.88	(1) 2.023 @ 24°	74.3649	155.5317	+0.0002
	4							81.1664		
94	5				do. + 4 . . .		(2) 2.023 @ 24°	77.8895	167.5540	+0.0005
	6							89.6640		
95	7				do. + 6 . . .		(3) 2.023 @ 24°	70.4122	157.9070	+0.0002
	8							87.4948		
96	1				20 drops N.S. R.P.		—	86.9974	153.8427	+0.0002
	2							66.8451		
97	3				- - - .		(1) 2.030 @ 24°	90.5405	178.5276	+0.0009
	4							87.9862		
98	5				- - - .		(2) 1.978 @ 24°	80.3833	165.6370	+0.0004
	6							85.2523		
99	7				- - - .		(3) 2.026 @ 24°	86.2962	161.8054	-0.0005
	8							75.5097		

Experiment to determine the electrochemical equivalent of zinc.

Three pairs of zinc plates were selected.

Plates 1 + 2 were of 0% pure electrolytic cast zinc, unamalgamated

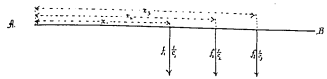
- 3 + 4 - - 5% Hg alloy) unamalgamated pure electrolytic zinc cast
- 5 + 6 - - 5% - - was amalgamated and used.

The solution was 1·11 sp. g. $ZnSO_4$, acidity 10 drops, raised to boiling point. These plates were set in 25 ct bottles but were not coupled by rubber connectors as in the ordinary meter bottle. No stoppers were placed on the bottles, which were in series with each other and a silver voltameter formed of a small glass beaker containing pure $AgNO_3$ and small silver plates about 6·5 sp. one in each dipping into it. The 4 voltameters were connected with a storage cell and resistance box with the British galvo. The test commenced about at 18.05 19.12.88 the current being steadily maintained at 10 m. amps, and the temp. of the room averaging about 20°C. All went well up to the evening of the 21st but on the morning of the 22nd the current was found interrupted by the fracture of the anode in the silver voltameter which had been allowed to dissolve too far and the dust debris of which had fallen to the bottom of the beaker. The following are the weights obtained by Mr Lawrence. The gain could not be obtained since the zinc cathodes had smutted.

Bottle No.	Metal	Weight empty 19.12.88	19.12.88 Sum	Observed joint weight	Difference	Weight empty 22.12.88	Loss	Gain	Ratio Zn to Ag	Chem. Eq.	Chem. Eq. of Zn
1	0% Zn	~~106.7577~~ 106.3297	215.0836	215.0836	+0.0002	106.1318	0.6219	—	0.29602	0.00032 Ag 3.310 × 10⁻⁴	63.709
2											
3	5% Zn amal.	121.8911	236.1613	236.1620	+0.0007	113.9231	0.6471	—	0.30502	3.442 × 10⁻⁴	66.323
4		114.5702									
5	5% Zn amal.	117.6819	229.2696	229.2698	+0.0002	117.0178	0.6641	—	0.31611	3.5385 × 10⁻⁴	68.085
6		111.5877									
7	Ag.	2.8168	5.9279	5.9278	−0.0001	0.7180	2.1098				
8		3.1091				5.2100	~~2.10~~ 2.1009				

The zinc were unmanished, and not heated or amalgamated before the test under these circumstances they would be liable to gain weight by oxidation the tendency being greatest in 1·2 Cent in 5 ct. To arrive at the loss of the silver plate, the debris in the beaker had to be collected and dried on a watch glass.

General Mathematical theory of the resultant fault determination in a circuit of known derivations.



Let AB be a conductor such as a telegraph line with derivations of $c_1\ c_2\ c_3 \ldots c_n$ who at distances $x_1\ x_2\ x_3 \ldots x_n$ ohms from A

Then let R be the insulation resistance from A

" " ρ " Part part of the insulation res: due to the resultant fault

" " X " " " " " " " " " resultant distance

Thus $R_x = \rho_x + X_x = x_1 + \frac{1}{c_1}$

Also $R_2 = x_1 + \dfrac{\frac{1}{c_1}(x_2 - x_1 + \frac{1}{c_2})}{\frac{1}{c_1} + \frac{1}{c_2} + x_2 - x_1}$

$= x_1 + \dfrac{c_2 x_2 - c_2 x_1 + 1}{c_1 + c_2 + c_1 c_2 (x_2 - x_1)}$ and since $(x_2 - x_1)$ is small and $c_1 c_2$ is also small we have approx:

$= \dfrac{c_1 x_1 + c_2 x_1 + c_1 x_2 - c_2 x_1 + 1}{c_1 + c_2}$

$= \dfrac{c_1 x_1 + c_1 x_2}{c_1 + c_2} + \dfrac{1}{c_1 + c_2}$

Also $R_3 = x_1 + \dfrac{\frac{1}{c_1}\left((x_2 - x_1) + \frac{1}{c_2}\left(x_3 - x_2 + \frac{1}{c_3}\right)\right)}{\frac{1}{c_1} + x_2 - x_1 + \frac{1}{c_2}\left(x_3 - x_2 + \frac{1}{c_3}\right)}$ simplifying and rejecting terms of the order $\Delta x\, c$ or $\Delta x c^2$ we have

$= x_1 + \dfrac{c_1 x_1 + c_1 x_2 - c_1 x_1 - c_1 x_2 + c_2 x_3 - c_2 x_2 + 1}{c_2 + c_3 + c_1}$

$= \dfrac{c_1 x_1 + c_2 x_2 + c_3 x_3}{c_1 + c_2 + c_3} + \dfrac{1}{c_1 + c_2 + c_3}$

Hence by induction

$$\left.\begin{aligned} \rho_n &= \frac{1}{\Sigma c} \\ X_n &= \frac{\Sigma cx}{\Sigma c} \\ \text{and } R_n &= \frac{\Sigma cx}{\Sigma c} + \frac{1}{\Sigma c} \end{aligned}\right\}$$

To a degree of approximation which increases with the number of derivations, and becomes rigidly true with an infinite number.

Also for a return circuit system the formulae become

$\rho_n = \frac{1}{\Sigma c}$

$X_n = \frac{\Sigma c\, 2x}{\Sigma c} = 2\,\frac{\Sigma cx}{\Sigma c}$

$R_n = 2\,\frac{\Sigma cx}{\Sigma c} + \frac{1}{\Sigma c}$

To repeat the measurement of the electrochemical equivalent of zinc the following experiment was arranged on the 24th and 25th December. Five couples of zinc and one couple of silver. The silver voltameters were formed of 2 silver plates each about 8×5 cm. wide and with the upper edge so cut that by bending it formed a triangle thus:— A silver wire passed through the triangle and depended upon the weight of the plate for contact. These plates were immersed in a 25% solution by weight of $AgNO_3$ prepared by adding 50 grs. pure $AgNO_3$ to 150 of distilled water.

The zinc cells were either 12 light bottles or 25 light tubes. The latter proved very fragile & couple #3 & 4 were upset through a fracture. The zincs were new 5% castings doubly amalgamated. They were amalgamated after boiling in hot mercury on the morning of the 24th. They were then left in the desiccator till the 25th when they were weighed and immersed the last being weighed at 23 o'clock. The solution was 1·054 $ZnSO_4$ from the chemical room acidulated until it took 35 drops of standard 10% solution (see page 63) to produce P.P. It was then boiled in a porcelain dish and then poured off into a stoppered bottle where it remained for 24 hours until required for use. The circuit through the 6 voltameters was closed through a storage cell, ammeter galvo: and 250Ω at 23h5m. 25.12.88— the current being 7 amp.

No.	Metal	Amalgam	Solution	Weight at 23h	Sum.	Joint weight	Discrepancy
1	5% cast zinc (Mercury)	amalgamated over night & dried in cold mercury boiling until hot	pure $ZnSO_4$ density 1·054 before boiling with H_2SO_4 added until 35 drops of standard solution required to produce P.P. then boiled in porcelain dish & poured off into a stoppered bottle where it remained for 24 hours until required for use	115·3053	234·7496	234·7496	0·0000
2				119·4443			
3				113·9077	233·8539	233·8543	+ 0·0004
4				119·9462			
5		amalgamated over night & dried in cold mercury boiling until hot		121·2429	238·7328	238·7335	+ 0·0007
6				117·4899			
7	pure zinc cast with 5% (Mercury) of distilled			116·8968	233·3804	233·3810	+ 0·0006
8				116·4836			
9				127·7305	251·9335	251·9343	+ 0·0008
10				124·2030			
11	Silver strip	New	25% sol: pure $AgNO_3$	8·3465	16·6409	16·6403	− 0·0006
12				8·2944			

December 26th Wednesday

Made up two new bottles as follows—

(1) 5% cast zinc unvarnished. Amalgamated hot in hot mercury. Solution 1·054 18 drops P.P. boiled. 25 lt bottle.

(2) 5% cast zinc unvarnished. Amalgamated cold in cold mercury. Solution 1·054 18 drop P.P. boiled. 25 lt bottle.

The only difference known lies in the amalgamation.

No. (1) developed speedily bubbles on its surface. No 2. speedily tarnished.

Commenced report on Meter work.

Measured the spec. res: of a saline solution made by adding 35 grs. $NaCl$ to 1000 grs. Infusion. The sp. gr. of the mixture was about 1·027 (at about 20°C temp. The resistance of a tube column 166 cms long and 1·105" = 2·81 cm. diam: was 7400. On cooling by ice application to 5°C. the res: fell to 8200 = 30·6 sp. res. The conditions of this measurement did not ensure any great degree of precision. The electrodes were of amalgamated zinc.

$R\,(1.00388)^{19} - R = 1.476\omega \qquad R = \dfrac{1.476}{(1.00388)^{19} - 1}$

$\log 1.00388 = 0.0016828 \times 19 = 0.0319732 = \log^{-1} 1.0764$

$1.476 \div 0.0764 = 19.3\omega$

$\therefore\ 1.005 = 0.0021661 \times 19 = 0.041159 = \log^{-1} 1.0993$

$1.476 \div 0.0993 = 14.86\omega$

Meter Experiments contd:—

To ascertain whether the strong current (averaging during working hours 50 amperes and reaching at times 100 amperes) passing through the platinoid strip mentioned on page 58 and placed in cot. with the compositions motor since the 13th inst. have caused any change in its res: I took it down and measured it as follows:—

2 Daniells bn in cot with legal 0·1ω and strip @ 18·8°C.

After the measurement the strip was replaced in the motor cot.

No. of Obs	Defl. on strip 332·4	Defl. on 0·1ω 336·0	Ratio strip to 0·1ω	Res. of strip @ 15°C	Res. of strip @ Temp	v	v²	0·6745 $\frac{\sqrt{v^2}}{\sqrt{n(n-1)}}$	Res. of strip @ 18°C	Res. @ 22·5°
1	338·9	337·0	0·99888	0·1000	0·099888	−0·000022	4·44 × 10⁻¹⁰	0·19471 × 0·0002	0·09965 ± 0·00004	0·09973
2	334·9	336·0	0·99635		0·099635	+0·00019	13·69 × 10⁻¹⁰	19471 × 0·00023		
3	333·9	336·7	0·99580		0·099580	−0·00004	1·69 × 10⁻¹⁰	1·47 × 10⁻⁵		
4	334·3	336·7	0·99649		0·099649	−0·00001	1 × 10⁻¹⁰	0·00004		
Mean	334·25	336·6	0·99647		0·099647	−0	5·3558 × 10⁻¹⁰ / 23·69 × 10⁻¹⁰ / 0·00023			
					0·09964					

The present res: referred to 22·5° is 0·09973ω ± 0·00004

" previous " " " was 0·09988 ± 0·00001

Difference 0·00015 = 0·15 % about 1/6 of 1%.

December 28th Friday. Interrupted at 8·20 the meter resistance test, dried and weighed the plates as follows:—

No. of Plate	Weight empty 22.12.88	Joint plate weight 22.12.88	Average temp	Shunted by a wire	Res. of shunt @ mean temp	Hydrometer reading under 4 corks	Weight empty 28.12.88	Sum	Joint weight 28.12.88	Joint gain	Joint loss
1	87·2212	167·9210	27°C	∞	∞	10	85·8230	167·9686	167·9688	0·0478	
2	80·6992						82·1458				
3	74·3849	155·5317	27°	2·023	2·025	20	74·8804	155·4945	155·4950		0·0367
4	81·1468						80·6141				
5	77·8987	167·5840	27°	2·023	2·025	10	78·7132	167·6104	167·6108	0·0568	
6	89·6853						88·8972				
7	70·4122	157·9070	27°	2·023	2·025	50	70·9577	157·7265	157·7260		0·1810
8	87·4948						86·7688				
9	76·9976	153·8427	7°	∞		20	85·5418				
10	66·8451						omitted				
11	90·3405	178·5276	7°	2·029	2·013	20	90·6275	178·4839	178·4843		0·0433
12	87·9863						87·8564				
13	80·3833	165·6370	7°	1·978	1·963	20	80·4742	165·5863	165·5864		0·0506
14	85·2523						85·1121				
15	86·2962	161·8054	7°	2·026	2·010	20	86·3331	161·7511	161·7515		0·0539
16	75·5097						75·4180				

No. Plate	Individual gain	Individual loss	Excess of gain over loss	Excess of loss over gain	Ratio of gain & loss to loss	Coefficient Electrolytic	Calculated Mean Res.	Mean Res.	Undivided current	Hours of Flow.	Appearance of Plate
1	1·46733	1·8982									dull
2	1·44666		0·0482								clean
3	0·5755										brilliant
4		0·6627		0·0368	2·531	1·531	3·10ω				clean
5	0·8237		0·0569								clean
6		0·7668			1·824	0·824	1·67ω	2·22ω			dull
7	0·5395										brilliant
8		0·7288		0·1813	1·940	0·940	1·90ω				dull
9	—	0·4556							10 microamps	94 hours + 20 hour intermission or 114 in all.	dull
10											bright
11	0·2870			0·0429	11·22	10·22	20·57ω				bright
12		0·1298									bright
13	0·0909			0·0493	10·38	9·38	18·41ω	22·9507			bright
14		0·1402									clean
15	0·0369			0·0548	15·87	14·87	29·8ω				bright
16		0·0917									clean

Motor Experiment, contd :-

December 29th Saturday :-

The last resistance test not having been very successful, arranged to repeat it as follows :-

The same zincs were raised to boiling point of water and amalgamated in fresh hot mercury. The solution 1·0544 was raised to boiling point in a large porcelain dish, and poured into the bottles as soon as possible. The tops of the bottles were then put on so that the solution might cool down without free access to the air. The density of the solution was found afterwards to have been increased to 1·065 on cooling, but it was not altered in the bottles. The weights were then taken as follows :- Observer Lawrence.

No. of plate	Weight before	Sum	Joint weight Ind.	Discrepancy	Bottle Bottles Nos	Shunted by @25°C	Acidity of solution	Current	Group
1	78·7310	142·3715	142·3712	− 0·0003	1-2	∞	10-15	0·009 amp	
2	63·6405								
3	94·1786	157·5915	157·5928	+ 0·0013	3-4	(1) 2·023			Warm
4	73·4159								
5	84·2353	150·8535	150·8555	+ 0·0020	5-6	(11) 2·023			
6	66·6182								
7	81·0620	167·3760	167·3760	+ 0·0015	7-8	(3) 2·023			
8	86·3125								
9	70·0398	149·5188	149·5192	+ 0·0004	9-10	∞			
10	78·6790								
11	78·4648	164·0258	164·0260	+ 0·0002	11-12	2 2·029 5 1·978 9 2·026 } 6·043			Cold
12	82·5610								
13	84·9529	173·3901	173·3906	+ 0·0005	13-14	4 2·002 6 1·990 12 2·023 } 6·015			
14	88·4372								
15	82·2462	177·7167	177·7175	+ 0·0008	15-16	7 2·012 8 2·027 10 2·021 } 6·060			
16	85·4505								

The current used in operation on these bottles at 21 o'clock.

Electrochemical equivalent Test:

The series of bottles started on the 25th were kept in operation on 7 minutes till the evening of the 28th when the current was reduced to 1 milliamp on account of the freezing on the silver cathode endangering the liquid circuit. The plates were removed and washed on the 29th in the morning and weighed the same evening. It was noticeable that although the freezing on the silver cathode extended near the top of the plate to about a perpendicular distance of 1 cm, the hard deposit clung firmly and did not seem to be shaken off by gentle washing. Weights as follows :-

No. of plate	Weight before 25.11.11	Joint weight 25.11.11	Weight after 29.11.11	Joint weight Sum	Joint weight Ind. 29.11.11	Gain	Loss	Mean of Gain − Loss	Elect. Equiv.
1	115·3053	234·7496	114·8389	234·6713	234·6707	~~0·0336~~	0·6664 0·6953	0·4273	0·396 x10⁻⁴
2	119·4443		119·8324			0·3881			
3	113·9077	233·8543	113·4204	233·7408	233·7405	0·3742	0·4873 0·1141	0·4308	3·424
4	119·9466		120·3204						
5	121·2129	236·7335	120·7560	238·6187	238·6188	0·3728	0·4569 0·1141	0·4299	3·417
6	117·4899		117·8627						
7	116·8968	233·3810	116·4050	233·2555	233·2555	0·2669	0·4218 0·1437	0·4294	3·413
8	116·4836		116·8505						
9	127·7305	251·9343	127·2400	251·8163	251·8165	0·3729	0·4906 0·1177	0·4315	3·430
10	124·2030		124·5759						
Ag 1	8·3465	16·6403	9·7493	16·6353	16·6353	1·4025	1·4056	1·4056	
Ag 2	8·2944		6·8860						
							Mean	0·4298	3·416 x10⁻⁴

The mean value is 0·0003416, but the couple that lost least (1-2) give 0·0003396. Ayrton's number is 0·0003393.
The mean difference from Ayrton's number is 0·7% and from 1-2 0·1%, the greatest error 1·2%.

Germicide experiments. continued from page 36.

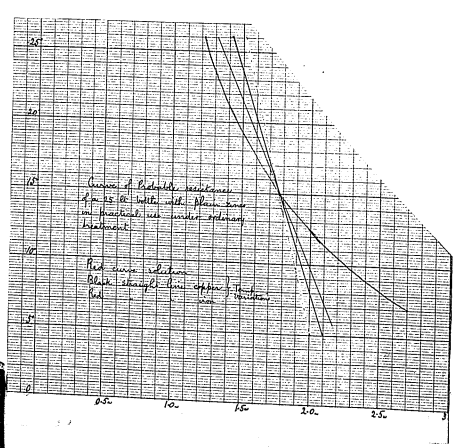
A series of experiments with caustic soda on the 12th December.
Prepared some Buchholtz Nutrient fluid as follows.

Phosphate of Potash 1 gr
Tartrate of ammon. 2.
Rock candy 20.
Distilled water 200.

Introduced this solution into 5 test tubes after sterilizing it by boiling repeatedly.

No. of tube	Weight of NaHO in tube	Weight of Buchholtz Nutrient	%	Date of first discovery of organisms	Remarks
1	0	50	0	Dec. 19th — 7 days	All these tubes were closed with corks but were opened almost daily for examination
2	0.5	49.5	1	" 21st — 9 "	
3	1.0	49	2	" 27th — 15 "	
4	4.0	46	8	" 29th — 17	
5	8.0	42	16	" still clear 31-12-98	

On the 31st Dec. the condition of these tubes is as follows:—
No. 1. Cloudy with thick white pellicle on the surface
" 2 Clear with amber color and contains a few live bacteria + budding cells
" 3 " " " " " fewer
" 4 " " " " " very few
" 5 " " " " " no visible " or



Meter Experiments contd.
December 31st Monday.

Set the electrolytical equivalent test to work at 16·30 relech. on 0·2 amp. Weighed plates carefully, filled the $AgNO_3$ solution, and prepared the Zn SO_4 solution by taking a solution of 200 grammes Powers & Weldemann salt added to some 1866 c.c. ag. dist. Their density was 1·085 before boiling in porcelain dish, after which 1307 c.c. were received at 1·087. The zinc were amalgamated in hot mercury, after dipping in boiling water. They were then chilled in cool water. Couples 1-2 3-4 7-8 9-10 were in circuit with the silver voltameter, and 5-6 was left in solution to examine the separate gain or loss.

Plate No.	Weight surfs before	Mean.	Mid point weight before	Weight surfs after	Sum.	Mid point weight after	Gain	Loss.	Difference	E.C. Equiv
1	116·3742	236·3410	236·3444	117·7745	236·3011	236·3020	1·4203			
2	119·9669			118·5266				1·4402	−0·0399	3.326×10^{-4}
							1·420			
3	119·4594	232·7214	232·7247	120·8915	232·7187	232·7197				
4	113·2620			111·8272			1·4321	1·4378	−0·0057	3.361
							1·435			
5	124·1676	244·6642	244·6645	124·1679	244·6562	244·6570				
6	120·5166			120·5083			0·0003	0·0053	−0·0050	~~3.235~~
7	112·8265	232·3575	232·3578	116·2658	232·3513	232·3520				
8	117·5310			116·0855			1·4393	1·4455	−0·062	3.335
							1·434			
9	116·0127	242·8635	242·8640	117·4517	242·8655	242·8660				
10	126·8508			125·4138			1·4390	1·4370	+0·0020	
							1·438			3·369
										Mean 3·348 $\times 10^{-4}$
Ag 1	8·3252	15·1517	15·1517	3·2850	14·9550			5·0704		
Ag 2	6·8263			11·6000			4·77374			
							4·7737			

The deposit on the zinc was homogenous and good. The silver plate anode was much consumed and lost a considerable quantity of black powdery material, which was however collected on a watch glass and found to amount to 54 mgrms. A small piece was lost of the gain on the cathode but an estimated quantity representing it was weighed and represented 34 mgrms. These corrections are introduced into the above figures. Taking the gain of the silver the mean elect. chem. eq. is 3.348×10^{-4} or 1·205 per amp. hour. Taking the mean of gain and loss. 3.442×10^{-4} or 1·242 - - - - The results are unsatisfactory as regards the silver voltameter.

January 2nd 1889 Wednesday

Interrupted the meter resistance with the following results.

Plate No.	Weight surfs 29.12.88	Sponge temp	Shunted by 0·25°	Res. of Shunt (0 mean 6.0)	Weight surfs 2.1.89	Sum of pairs	Mid point weights 2.1.89	Gain	Loss.	Res Ratio	Res
1	78·7310	26°	∞		78·5273	142·3421	142·3420	0·7143	0·2037		
2	63·6105				63·8148						
3	84·1756	26°	2.023	2.025	84·6658	157·5690	157·5692	0·4899	0·5124	1.612	1.239
4	73·4134				72·9035			0.50			
5	84·2323	26°	2.023	2.025	84·7675	150·8080	150·8085	0·4822	0·5277	1.601	1.217
6	66·6162				66·0405			0.50			
7	81·0620	26°	2.023	2.025	81·5446	167·3314	167.3320	0·4826	0·5257	1.608	1.221
8	86·3125				85·7868			0.50			1.226
9	70·9298	T	∞		71·6214	149·8663	149·8667	0·7816	0·8341		
10	78·6790				78·2449			0.783			
11	78·6648	T	6.043	6.00	78·9910	160·9865	160·9868	0·5262	0·5655	1.480	2.880
12	82·2610				81·8955			0.50			
13	84·9520	T	6.065	6.02	85·5010	173·3516	173·3519	0·5481	0·5866	1.4224	2.553
14	88·3972				87·8506			0.548			
15	82·2662	T	6.060	6.02	82·8273	167·7192	167·7196	0·5611	0·5586	1.4243	2.673
16	85·4505				84·8919			0.559			
											2.702

Highest temp. for January 57° } 45° Range
Lowest - - - 12°
Maximum Rainfall - - 1.47"
Highest Bar. reading - - 30.281"
Lowest - - - - 29.370"
Range 0.911"
Total Rainfall 5.05"

Highest temp. for February 50°F } 50° Range.
Lowest - - 0°
Maximum Rainfall 0.98"
Highest Bar. reading 30.614"
Lowest - - - 29.346
Range 1.268"
Total Rainfall 2.21"

Meteorological Record commencing 1st Jan. 1889.

Month	Day of Month	Time	Barometer Reading Eng.	Barometer Reading Cmm.	Temp. of Air Fahr.	Reduced Bar. Eng.	Reduced Bar. Cmm.	Rep. at 32°F	Max. Temp. Max.	Min. Temp. Min.	Dry Bulb Temp. Day	Wet Bulb Temp. Wet	Rainfall Eng.	Remarks
January	1st	Noon	29.946	76.07	78°	29.810		75.73	36°	23°	40°		0.	Fair Cum. Strats
"	2nd	"	29.870	75.87	76°	29.740		75.46	30°	23°	29°		0	Cloudy, Nimbus
"	3rd	"	30.086	76.42	74.5°	29.963		76.10	29.5	29°	29°		0	Fair Light Mist Clo.
"	4th	"	30.100	76.46	78°	29.962			32°	32°	32°		0	
"	5th	"	30.058	76.26	78°	29.999			49°	31°	49°		0.05	Wet. Nimbus NE.
"	6th	"	29.545	75.05	70°	29.433			42	38	41°		1.47	Rain Nimbus NE.
"	7th	"	29.500	74.93	73°	29.377			42	37	40		0.31	Rain Nimbus NW.
"	8th	"	29.778	75.64	69°	29.667			43	35°	43		0.01	Fair Clear
"	9th	"	29.430	74.76	62	29.376			45	30	44		0.58	Rain Twist
"	10th	"	29.648	75.31	50°	29.594			57	34	39		0.42	Fair Cu. Cum. Strat.
"	11th	"	30.029	76.27	58°	29.951			42	31	37		0.0	Fair Nimbus W. mist
"	12th	"	30.232	76.79	66°	30.130			39	28	34		0.0	Fair Clear W. hazy
"	13th	"	30.248	76.83	62°	30.158			35	20	34		0.0	Fair Clear
"	14th	"	30.236	76.80	63°	30.143			36	24	36		0.0	Fair cloudy
"	15th	"	30.336	77.06	57°	30.281			37	19	29		0.0	Fair Clear
"	16th	"	30.134	76.54	58°	30.056			37	26	37		0.0	Fair Clear.
"	17th	"	29.576	75.13	72°	29.456			56	37	56		1.05	Rain. SW. mist
"	18th	"	29.806	75.71	70°	29.692			47	22	40		0.00	Fair Clear NW.
"	19th	"	30.314	77.00	62°	30.224			46	25	28		0.	Fair Clear NW.
"	20th	"	30.292	76.94	37°	30.277			27	15°	21		0.	Cloudy
"	21st	"	29.438	74.78	47°	29.393			29	21	36		0.55	Snow
"	22nd	"	30.306	76.98	60°	30.222			34	25	31		0.	Clear
"	23rd	"	30.400	77.21	52°	30.340			34	12	34		0	Cloudy
"	24th	"	30.186	76.68	53°	30.123			39	16	39		0	Cloudy
"	25th	"	29.984	76.17	50°	29.930			40	28	39		0.03	Fair
"	26th	"	29.910	75.97	48°	29.862			43	24	42		0	Overcast
"	27th	"	29.231	74.26	52°	29.168			45	34	45		0.55	Overcast
"	28th	"	29.414	74.71	47°	29.369			36	24	25°		0	Clear
"	29th	"	30.004	76.22	55°	29.935			28	17	17		0	Clear
"	30th	"	29.773	75.62	60°	29.699			40	20	39		0	Clear
"	31st	"	29.802	75.70	49°	29.751			45	28	98		0.01	Clear
Febry.	1st	"	29.722	75.50	56°	29.650			34	19	34		0.0	Clear
"	2nd	"	29.472	74.91	46°	29.410			39	31	39		0.0	Clear
"	3rd	"	29.848	75.80	56°	29.776			39	11	24		0.0	Overcast
"	4th	"	29.460	74.84	70°	29.346			43	25°	25°		0.0	"
"	5th	"	29.602	75.20	62°	29.512			44	16	18		0.10	Cloudy
"	6th	"	29.870	75.86	57°	29.795			20	10	20		0.0	Cloudy
"	7th	"	29.984	76.17	58°	29.906			30	10	30		0.0	Overcast
"	8th	"	29.856	75.84	68°	29.748			36	21	36		0.08	Clear
"	9th	"	30.006	76.25	45°	29.967			39	21	35		0.0	Cloudy
"	10th	"	29.724	76.00	62°	29.636			39	17	32		0.0	Overcast
"	11th	"	29.606	75.21	59	29.525			32	22	29		0.07	Clear
"	12th	"	29.610	75.22	50°	29.541			30	12	19		0.	Clear
"	13th	"	29.884	75.91	52°	29.818			24	10	24		0.	Clear.
"	14th	"	30.224	76.77	63°	30.131			32	11	32		0.	Clear
"	15th	"	30.154	76.59	65	30.055			49	32	32		0	Rain
"	16th	"	29.504	74.95	47	29.459			44	33	44		0.98	Rain
"	17th	"	29.[illegible]	76.00	60	29.879			44	34	35		0.56	Rain
"	18th	"	29.924	76.00	61	29.837			42	27	28		0.02	Clear
"	19th	"	30.306	76.98	65	30.207			36	16	27		0.0	Clear
"	20th	"	30.602	77.73	67°	30.497			36	15	27		0.0	Clear
"	21st	"	30.220	76.76	69°	30.115			36	25	35		0.0	Overcast
"	22nd	"	30.364	77.15	62°	30.284			39	13	13		0.0	Clear
"	23rd	"	30.676	77.92	59°	30.595			30	0	15		0.00	Clear
"	24th	"	30.322	77.03	60°	30.238			31	14	22		0.01	Clear
"	25th	"	30.702		62°	30.614			39	12	28		0.01	Clear
"	26th	"	30.476	77.40	68°	30.366			34	26	34		0.19	Snow
"	27th	"	30.386	77.19	69°	30.395			39	34	39		0.18	Overcast
"	28th	"	30.370	77.17	71	30.261			45	26	40		0.	Clear
Mar	1st													

Meter Experiments contd:—

The resistance of the bottles observed with 1 mamp just before removing the bottles was

1/12	1·055	3/14	0·950	5/16	0·920	7/18	0·900	Mean 0·955
9/10	1·750	11/12	2·150	13/14	2·050	15/16	2·050	Mean 2·00

These readings are respectively 22 % and 26·5 % less than the averages res: by weight.

The resistance of the solution at the temperature of 7° + 26° should be

$38 + 0{\cdot}0088 \times 43 - 0{\cdot}9313 \times 7 = 38 + 0{\cdot}38 - 0{\cdot}65 = 37{\cdot}73$ ratio 1·915

$38 + 0{\cdot}0088 \times 676 - 0{\cdot}9313 \times 26 = 38 + 5{\cdot}95 - 24{\cdot}22 = 19{\cdot}73$ or 52·2 % less

The ratio between the averaged res. is 2·205 or 45·4 %.

January 7th Monday

Took the sp. g. of different plates of cast zinc as follows:—

No. of plate	Valley	Quality	Weight in air	Weight in water	Difference	Sp. g.	Observer
1	1	Small cast	88·50	76·13	12·37	7·15	Lehmann
2	2	- -	102·25	88·09	14·15	7·22	
3	3	- -	94·95	81·80	13·15	7·22	
4	4	- -	105·00	90·46	14·54	7·225	
5	5	- -	99·68	85·92	13·76	7·250	
6	5	Cast metal pile	103·82	89·62	14·20	7·31	

On the cost of power
required for the electrodeposition of pure copper
from pure copper sulphate solution.

The ampere will deposit 1·18 grammes of copper per hour or $\frac{1}{384}$ lb.

Taking the sp. res: of solution at 50°, the distance between the plates at $\frac{1}{2}$" = 1·25 cms, then the resistance will be $\frac{75}{S}$ where S is the surface in sq. cms. If S be the square metre the conductivity becomes 133 mhos and the current is 133E per sq. metre E being the bank P.D. Taking E at 1·8 the current would be 133 ampere per sq. meter. Suppose that through polarization and other causes the actual current at unit P.D. would be 60 amperes, then the deposition of 1 lb. would take 6 hours per sq. meter, and 133 Watts or 799 = say 800 Watt hours per lbof metal. that is $1\frac{1}{10}$ HP hour per lb:

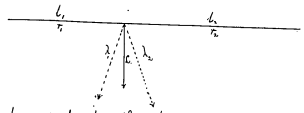
On the cost of power in the Laboratory).

Coal @ \$3·25 per ton = 3·25/2240 = 0·145 cts per lb.
5·25 lbs per HP. hour = 0·762 " per HP hour.
@ 120 volts the ampere = 1/746 HP. or 1 ampere Hour = 0·152

Water @ 18 cent per 1000-gallons = 0·018 cts per gall;
" 50 lbs per HP hr = 1·25 galls = 1·5 galls per amp hr. 0·027

0·179

The conditions under which the fall of potential on a given section may be a minimum.



Let l_1 and l_2 be the two portions of the section in feet
r_1 - r_2 - - resistances in ohms per foot of the conds.
$\mathcal{L}$ be the res: of the N.R.F.
λ_1 and λ_2 be the resistances of the corresponding portions of NRF
also let $r_1 = nr_2$

Then $\lambda_1 = \mathcal{L}\left(1 + \frac{l_1 r_1}{l_2 r_2}\right)$ and $\lambda_2 = \mathcal{L}\left(1 + \frac{l_2 r_2}{l_1 r_1}\right)$

$\sigma_1 = K \frac{c_1}{c_1+c_2}$ $\quad \sigma_2 = K \frac{c_2}{c_1+c_2}$

The fall of potential will be $\dfrac{E\, l_1 l_2 r_1 r_2}{l_1 l_2 r_1 r_2 + \mathcal{L} l_1 r_1 + \mathcal{L} l_2 r_2}$

$$= \frac{E\, l_1 l_2 n r_2}{l_1 l_2 n r_2 + \mathcal{L} l_1 n + \mathcal{L} l_2}$$

For a minimum we have $\frac{dD}{dn} = 0$

$$\pi \quad \frac{E\, l_1 l_2 r_2 (l_1 l_2 n r_2 + \mathcal{L} l_1 n + \mathcal{L} l_2) - E\, l_1 l_2 n r_2 (l_1 l_2 r_2 + \mathcal{L} l_1)}{(l_1 l_2 n r_2 + \mathcal{L} l_1 n + \mathcal{L} l_2)^2} = 0$$

or $l_1 l_2 n r_2 + \mathcal{L} l_1 n + \mathcal{L} l_2 = l_1 l_2 n r_2 + \mathcal{L} l_1 n$ $\quad$ or $n = \infty$

The fall of potential is always $\quad E \times \dfrac{1}{1 + \mathcal{L}\left(\frac{l_1 r_1 + l_2 r_2}{l_1 r_1 l_2 r_2}\right)}$

calling $l_1 r_1$ R_1 and $l_2 r_2$ R_2

this becomes $\quad E \times \dfrac{1}{1 + \mathcal{L}\left(\frac{R_1 + R_2}{R_1 R_2}\right)}$

and if c_1 and c_2 be the respective conductivities in mhos $\quad E \times \dfrac{1}{1 + \mathcal{L}(c_1 + c_2)}$

If $\mathcal{L} = \frac{1}{K}$ $\quad = E \times \dfrac{K}{K + c_1 + c_2}$

Similarly the fall in the NRF $= \quad E \times \dfrac{c_1 + c_2}{K + c_1 + c_2}$

From the above if a section of length $\mathcal{L}$ (feet) have a total number N of lamps at distances l_1 and l_2 from the termini to the center of distribution the number n_1 of lamps fed from the side l_1 will be $N\left(\frac{l_1}{\mathcal{L}}\right)$ and from the side $l_2 = \left(N \times \frac{l_2}{\mathcal{L}}\right)$

Multipolar Dynamo Characteristic Data

January 16th Wednesday.

Took the characteristic curve measurements of the Octopolar Dynamo after having approximately balanced its magnetism.

Time	Revs. per min.	Volts on Magnets	Amperes thru magnets	Amperes per coil of field	Voltage indicated	Reduced to 800 revs.	
15·35	815	–	3·4	0·85	28		
			3·6	0·9	29		
			3·8	0·95	30		
			4·0	1·00	33		
		20	4·5	1·13	36		
		22	5·4	1·35	42		
		24	6·8	1·7	54		
		30	7·5	1·88	62		
		34	9·0	2·13	70		
		40	11·0	2·75	81		
		49	13·0	3·25	88		
		55	14·5	3·63	95		
		58	15	3·75	97		
		64	16·5	4·13	103		
		67	17	4·25	105		
		69	19	4·75	108		
		74	20	5·00	114		
		83	22·5	5·63	119		
		90	24	6·00	124		
		94	25	6·25	125		
	825	108	29·5	7·38	132		
		–	30	7·50	135		
			31	7·75	137·5		
			32	8·0	139·5		
			33	8·25	143		
			34·5	8·63	144		
			35·5	8·88	145		
			36	9·00	146		
			37·0	9·25	149		
			38·0	9·5	151		
			38·5	9·63	152		
			39·5	9·88	153		
			40·0	10·0	153		
			41·5	10·38	154·5		
			43·0	10·75	156·5		

Transformer trial January 23rd after its repair.

Voltage on primary terminals 960
Amperes in primary circuit 7·5 Watts in primary circuit 7200

Voltage on secondary terminals 104
Amperes in secondary circuit 51·5 Watts in secondary circuit 5170
101 Lamps sustained.

When running without load current in primary cct 2·5 Watts 1920

Fields excited separately. Speed not known.
Res. of secondary 0·17 Loss in Watts 150·88 in Volts 8·75
- - primary 4·7 - - 264·35 35

Of the 7200 Watts absorbed 7165 were received magnetically
of the 5258 - - circuit 5170 - yielded externally

Total efficiency 72% electrical efficiency 73·4

Meter Tests.
January 24th Monday.

Following comparison made between a special meter of the Standardizing Bureau and our two standards. This special meter was designed to have a constant of 4 and of 8 on its two sides respectively. Passed the 35 ampere current in the lamp test room through it in series with the two standards in multiple. The solution used had been boiled afresh by Lehmann (it acidity) was 5–10 drops. The density was 1·0554 and it contained no appreciable amount of impurity. The zincs were all of plane, rolled material previously used but amalgamated hot. It was subsequently found that some of this amalgam of a thick pasty consistency had remained in the holes in spite of the ordinary precautions and the error of loss was perhaps due to the fact that some of this amalgam was found on the connecting screws:

No. of plate	Weight in grs. removed	Sum	Joint weight removed 21.1.29	Placed in Meter	Weight - grs. adding 24.1.29	Sum	Joint weight obtained 23.1.29	Gain	Loss
1	81·4469	159·7043	159·7053	A. Whit meter left hand side	· 81·5520	159·6745	159·6755	0·1055	
2	78·2575				· 78·1225				0·1350
3	83·5516	167·8003	167·8010	0·99 10 Sh.	Pt·1113	167·7975	167·7385	0·5597	
4	84·2487				· 83·6262				0·5225
5	82·3478	169·0889	169·0895	0·9954 Sh.	· 82·8577	168·9935	168·9920	0·5093	
6	86·7411				· 86·1358				0·6053
7	83·9715	169·5215	167·5220	B. Whit meter Right hand side	Pt·1782	167·4732	167·4735	0·2067	
8	83·5500				· 83·2950				0·2550

The test extended over 48 hours out of which the current was supplied for 35. The mean current was about 32 amperes making up a rough estimate of 1120 ampere hours. The bottles were removed and the plates dried and weighed. Something had commenced on the plates in the standard meters

No. of plate	Rough Lots.	Loss cold for meter error	Ampere-hours	Total ampere-hours	Ampere hour assuming meter 4.29	Ampere-hours assuming the meter one	Mean of loss + gain	Corresponding constants
1								
2	0·0298				1080	7·46	0·1253	1002·4 8·036
3	0·0625							
4		0·6238	509·7	1007·0				
5	0·0969							
6		0·6087	497·3					
7	0·0480				1020	3·95	0·2309	·923·6 4·36
8								

Owing to the existence of this discrepancy the plates were reamalgamated hot and the test repeated.

Comparison of the resistance of a platinoid strip with legal standard.

Jany 23rd 89

Connected the 0·1 ω Bergmann standard, the strip fastened round a table and a resistance box with a storage cell, and took following deflections beat with a f.s. of 300 divs (Taken as 290 for scale error) to the left.

No. of Obs.	Deflection on strip (full)	Deflection on 0·1ω (full)	Res. of 0·1ω @ 18·3°C	Difference (strip − ω)	ω	ω²	$\sqrt{\frac{\Sigma\omega^2}{n(n-1)}}$	Value of strip @ 18·3	Temp. at which strip carried	
1	571·9	569·4	0·09998	+ 2·5	+ 0·08	0·0064	0·02×0·09 = 0·0074	0·09991 × 572·6/572	−2·3°C	
2	571·0	568·6		+ 2·4	+ 0·18	0·0324				
3	570·0	567·6		+ 2·4	+ 0·19	0·0324				
4	569·1	566·8		+ 2·3	+ 0·28	0·0784		Diff = 2·58 ± 0·07	0·10043 ± 0·00001	
5	561·7 ~~1~~	562·0		+ 2·7	− 0·12	0·0144				
6	581·7	579·4		+ 2·3	+ 0·28	0·0784				
7	582·6	579·4		+ 3·2	− 0·62	0·3844				
8	582·5	579·7		+ 2·8	− 0·22	0·0484				
~ Scale error				Mean 2·58		Σω² 0·6752				

Repeated test Jany 25th with greater care. as follows — Temp. 0·1ω in bath 108° air 13·3 f.s. 300 taken at 320.

No. of Obs.	Deflection on strip (full)	Deflection on 0·1ω (full)	Res. of 0·1ω @ 13°C	Difference (strip − ω)	ω	ω²	$0.47143\sqrt{\frac{\Sigma\omega^2}{5\times4}}$	Value of strip @ 18·3	Temp. at which strip carried	
1	627·5	626·5	0·09992	+ 1·0	0·5	0·25	0·15081×1·05 = 0·16	0·09992 × 630/630	17°C.	
2	629·0	628·5		+ 0·5	0·0					
3	630·6	629·5		+ 1·1	0·6	0·36				
	Battery renewed						Diff = 0·53 ± 0·16	0·09991 ± 0·00024		
4	626·2	627·0								
5	628·0	628·6		+ 0·1	0·5	0·25				
6	629·1			− 0·05	0·5	0·25				
				Mean 0·53 +		Σω² = 1·11				

Joined up this strip in cct. with the 1000 Amp. large platinoid shunt the two triple strips of a large 700ω light Bergmann meter and the 5 volt Mains with the 40 Ampère meter in cct.

The 0·1ω strip was shunted by 1000ω and of this 1000ω the P.D. at 17 was led off to the galvanometer.

First comparison full 1000 Amp. shunt in series.

f.s. 320 taken at 310

No. of Obs.	Deflection on 0·1ω shunted	Deflection on 1000 Amp. shunt	Res. of strip at 18·7°C	Difference 0·1 − strip	Ratio for shunt	0·9503×0·09995	0·09495 × 1000/1000	Res. of shunt @ 16°C.	
1	655	623	0·09995	32	1·052				
2	655	623		32	minority				
3	657 zero rest	624		33	0·9503	0·09498	~~0·0949~~ 1·615	0·0001615ω	
4	650	617		33					
5	654								
	654·3	624·8		Mean 32·5					

General plan of strip

0·050009	0·02497	0·02241	0·01244	0·00620
		0·02485	0·01244	0·00620
	0·04992			

Total res: 0·09991 = @ 13·3°C.

Subdivision of strip
January 25th omitted:-

No. of Obs.	Deflin on entire ½ strip	Deflin on subdivided ½	Differences	Mean Diff	Ratio	Value of strip @ 13·3°	Value of entire ½	Value of subdivided ½		
1	669·7	662·8	6·9							
2	671·0	663·5	7·5 } 7·3							
3	671·8	664·3	7·5							
4	672·7									
	Probent current									
		663·9		3·5	666·5 / 663·	0·09991	0·050056	0·04992		
5	664·2	664·5	−0·3 } −0·2							
6	665·0	665·0	0·0							
	Reversed current									
7	667	660	7·0 } 7·0							
8	668	661	7·0							
9	668·6									

Corresponding test of ¼ lengths

No. of Obs.	Deflin on entire ½ strip	Deflin on subdivided ¼	Differences	Mean Differences	Ratio	Value of ½ strip	Value of entire ¼	Value of subdivided ¼		
1	681·8	682·5	−0·7							
2	682·3	683·0	−0·7							
3	683·0									
	Battery	reversed		+ 3·2	683·2 / 680·	0·04982	0·02497	0·02485		
4	683·5	677	6·5							
5	685·5	678	7·5							
6	686·5									
	Reversed current									
7	681·1	682·6								
8	682·6	682·1	−0·5							
		683·0	−0·6							

Corresponding test of ⅛ lengths.

No. of Obs.	Deflin on entire ¼ strip	Deflin on subdivided ⅛	Differences	Mean Differences	Ratio	Value of ¼ strip	Value of entire ⅛	Value of subdivided ⅛		
1		500·5								
2	499·5	501·6	−2·1							
3	500	502·5	−2·5							
	Battery	reversed		−1·0	501 / 500	0·02485	0·01244	0·012441		
4	502·8	502·5	+0·3							
5	493·5	493·0	+0·5							
		493·5								

Corresponding test of 1/16 lengths.. also of 1/32

No. of Obs.	Deflin on entire ⅛ strip	Deflin on subdivided 1/16	Differences	Mean Differences	Ratio	Value of ⅛ strip	Value of entire 1/16	Value of subdivided 1/16		
1	·	550								
2	552	550·6	1·4							
3	552·8	551	1·8							
	Battery	reversed		2·6	552·1 / 550·5	0·01244	0·00621	0·00620		
4		556·5								
5	560·5	557·5	3·0							
6	561·5	557·5	4·0							
1		286·3								
2	288·5	287·4	1·1							
3	288·8	287·9	0·9	3·6	289·6 / 288·	0·00620	0·00312	0·00308		
4	288·5	279·0	6·5							
5	288·0	279·0	6·0							

Special Meter test. (continued from page 75)

The trial was repeated with the same zinc reamalgamated hot, the holes carefully cleaned and the rods rewamished. The solution the same quality as that last employed except that it was rendered alkaline by the addition of zinc hydrate until a permanent opacity was obtained. It was then filtered and poured into the bottles. On this occasion smutting was noticed in both the standard meters. The zinc all became hydrated.

Meter Nos.	Weight obtained during 24.1.89	Sum.	Joint weight obtained 24.1.89	Read in meter	Weight obtained during 24.1.89	Sum	Joint weight obtained 24.1.89	Gain	Loss.
1 2	83·4645 81·8693	165·3338	165·3345	0·09980522	84·0060 81·3458	165·3518	165·3530	0·5415 (0·5330)	0·5235
3 4	83·4221 81·3882	164·8103	164·8115	0·09945522	83·9639 80·8733	164·8372	164·8380	0·5418 (0·5344)	0·5149
5 6	86·0362 84·1933	170·2295	170·2305	A	86·1549 84·0937	170·2486	170·2495	0·1187 (0·1193)	0·0996
7 8	83·0980 77·6664	160·7644	160·7647	B. (Trold Meter)	82·8915 77·8945	160·7860	160·7865	0·2281 (0·2297)	0·2065

The test commenced at 13.0 24.1.89 and ended at 12.0. 26.1.89 the current being about 30 amperes on the 130 volt cct. in the lamp test room, and the temp. about 23.5°C.

Meter Nos.	Sample Gain	Loss with gain for meter	Ampere hrs	Total Amp hrs	Amp hrs by constants of 44	Constants from 88 meter	Mean of Loss & Gain 2 obs	Similar Constants.	Mean Constants
1 2	0·0185	0·5245	428·5	~~851·6~~			0·5336	436·0 870·1	
3 4	0·0265	0·5378	422·1				0·5313	434·1	
5 6	0·0190			~~796·8~~	796·8	8·55	0·1092	874	7·97
7 8	0·0221			~~826·0~~	826·0	4·13	0·2173	869	~~4·095~~

Made a third test on the 28th (Jany) as follows:–

Meter Nos.	Sample gain	Loss with for meter	Ampere hrs	Total ampere hrs	Amp hrs by constants 44 & 45	Constants from 88 meter	Mean loss & gain	Similar constants.	
1 2	−0·0063			1160×8 928			0·1389	1289×8 ~~1181~~ 1107	7·64
3 4									
5 6	−0·0025	0·6570	537·9	1081·4			0·6592 0·6587 (1·2978)	1061 ~~881~~	
7 8	+0·0542	0·6651	543·5						

Test of Copy (maker of standard 0·1 legal ohm.
January 28th

No of Obs.	Deflcn on Copy	Deflcn on Standard	Difference	Temp Std	Temp Copy	Mean Diff.	Value of Std @ Temp	Value of Copy @ temp	Mean	Temp. at which Copy correct
1		675·2		°C	°C					
2	676·5	675·2	1·3	14·4°	14·8°	1·4	0·09986	0·10007		
3	676·5	675·3	1·2							
4	676·6	674·9	1·7							
5	676·8	674·5	1·3							
6	676·5									
7	672·5	670·8	1·7	14·4°	15·2°	1·8	0·09986	0·10014		
8	673·2	671·2	2·0							
9	673·8	Batt. reversed								
10	673·3	672·0	1·3	14·6°	15·4°	1·8	0·09987	0·10015		
11	670·4	668·2	2·2							
12	670·0									
13		658·8	1·2							
14	659·5	659·5	0·0			0·0				
15	659·5	659·5	0·0	15°	15°		0·09988	0·09988	0·09988 @ 15°C	21°C.
16	659·5	Batt: reversed								
17	659·2	660·6	−1·4			−1·4		0·09960		
18	659·8									
19	661·2	658·1	3·1	15·4°	15·6°	1·6	0·09990	0·10018		
20	661·5	658·5	3·0							

Repetition of test on 7th February

No of Obs.	Time	Deflection on Copy	Deflection on Legal ohm	Temp Std	Temp Copy	Difference	Mean Diff.	Value of Std @ 16·6°C	Value of copy @ 17·2°C	Temp. at which
1	16.46	671·5	673·8	16·6°C	17·2°C	+2·8				
2	16.48	672·0	673·6			+1·9	1·9	0·09993	0·10022	7°C.
3	16.50	671·5								
	Battery + galvo. reversed zero set									
4	16·52	670·5	671·8			+1·8				
5	16.54	669·6								

An analysis of the conditions of running in a motor.

Let E be the P.D. at the motor terminals.
" a - - res: of the armature
" l - - length of wire on its periphery traversing lines of force.
" v - - circumferential velocity of this wire.
" z - - average strength of magnetic field
" c - - current in the armature.
" e - - counter emf of the armature.
" τ - - torque
" f - - friction
" w - - work per second or activity

1st suppose the field magnets to be separately excited.

Then the current is $\dfrac{E-e}{a} = \dfrac{E - lvz}{a}$

the pull tangentially is $= lz\left(\dfrac{E - lvz}{a}\right)$

Under all conditions of activity, w must not vary widely and in the activity $w = lvz\left(\dfrac{E - lvz}{a}\right)$ z is the only variable.

$$\frac{dw}{dz} = lv\left(\frac{E - lvz}{a}\right) - \frac{lv}{a} \times lvz$$

$$= \frac{lv}{a}(E - 2lvz)$$

$\therefore$ if $e < \dfrac{E}{2}$ w increases by increasing z

" $e > \dfrac{E}{2}$ w diminishes " " "

So that when the efficiency is over 50% the activity is increased by weakening the field, and when the efficiency is under 50% the activity is increased by strengthening the field.

The commercial efficiency of a motor (series or shunt wound) is

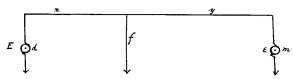
$$\eta = \frac{e}{E}\,\frac{\dfrac{E-e}{a} - \gamma}{\dfrac{E-e}{a}}$$ where γ is the minimum current that will run the motor up to speed unloaded.

Hence the maximum value of η is under the condition

$$(E-e)c = E\gamma$$

or the energy expended as heat in the armature at work must equal the total energy expended on running the motor light. This equation also takes the form

$$(E-e) = \sqrt{Ea\gamma}$$



If d be the res: of the dynamo armature E its internal emf, m the res: of the motor, e its internal e.m.f x and y the resistances of the intervening line up to the N.R.F of res: f. Then

$$C_x = \frac{E(f+y+m) - ef}{(x+d)(f+y+m) + f(y+m)}$$

$$C_y = \frac{Ef - e(f+x+d)}{(x+d)(f+y+m) + f(y+m)}$$

$$C_f = \frac{E(y+m) + e(x+d)}{(x+d)(f+y+m) + f(y+m)}$$

Test of a 700 Light meter made by Bergmann -B:

Placed this meter in the 100 ampere lamp-test circuit in series with the carpenter's shuntstrip 0·1 strip divided into 2 branches ~~[illegible]~~ and having thus a resistance of approximately 0·025ω. The terminals of this 0·025ω were led to two separate 25 ft bottles through 295' [illegible] so that a double meter was thus formed. The temp: of this strip commenced at noon on the 23rd [illegible] reached about 55°C. The test lasted a period of 6 days and some 88 hours of current. and ended at noon on the 4th

Read Plate	Weight empty 24.1.09	Weight empty 4.2.09	Gain	Loss	Mean Loss	Amp. Hrs.	Ratio			
1	352·7085	351·2211		2·5674						
2	350·2565	352·9562	2·4997							
3	354·9307	356·5257	2·4950							
4	353·0815	350·5242		2·5573						
5	352·2905	334·8571	2·5576							
6	352·8822	349·9970		2·6232	2·5743	2103×3 = 6309×29 = 6157	1·011			
7	352·5905	355·1016	2·5111							
8	350·1948	347·6380		2·5568						
9	329·5520	326·0229		2·5291						
10	331·2440	333·5132	2·4692							
11	349·7038	347·0916		2·6122						
12	353·0319	355·7216	2·6897							
13	86·6574	86·0246		0·6328						
14	86·0523	84·6470	0·5947		0·6319	6086				
15	83·5559	84·1415	0·5856							
16	76·6513	76·0203		0·6310						

The solution used was boiled 1.054 from ch. vom. sol: 5 strips used
The plates kept clean but were all smutted so that the gains are not reliable.
The following test was made of this strip shunt. 7th Febry. 09

Read No.	Time	Deflection on 4 Std ω	Deflection on Shunt	Difference	Mean Diff	Temp. Std 4	Ratio	Value of Std @ 4°C	Value of Strip @ 17°C.	Value @ 55°C.
1	16·51	660·9	660·8	0·						
2	16·53	659·8	660·7	+ 0·9						
3	16·54	659·0	659·9	+ 0·9						
	Batty: + galv: reversed zero not				0·7+	17°C.	$\frac{6607}{660}$	0·025ω	0·025ω	0·252ω
4	17·0	655·2	659·5	+4·3						
5	17·02	655·5	660·3	+ 4·8						
6	17·04	665·1	660·5	−4·6						
	Batty + galv: reversed zero not									
	17·08	656·7	655·5	−1·2						

$\frac{0.0252}{297} = 0.848 \times 10^{-4}$ so that proportion of current in bottle $= \frac{1}{1.179 \times 10^4}$

$\frac{0.6319 \times 1.179 \times 10^4}{1.2224} = 6086$ ampere hours.

Agreement of mean values within 1·1%

1ω shunted by 1000ω = joint res. of 0.9991 ω

1ω " " galv. 550ω = 9.82ω joint res.

Multiplying power $\frac{999.82}{9.82} = 1018$

$\therefore$ true res. $= \frac{0.99993 \times 656.4}{1018 \times 655.0} = \frac{6.5595}{666680} = 0.0000982$

$= 0.0000 97985$ @ 0°C.

0.1ω shunted by 700ω = joint res. $\therefore$ 0.1ω

10ω " " 550 = 9.82ω joint res.

Multiplying power $\frac{999.92}{9.82} = 71.28$

$\therefore$ true res. $= \frac{0.09993 \times 340}{71.28 \times 335.3} = \frac{3397}{23985} = \frac{33.97}{2.39 \times 10^4} = 14.21 \times 10^{-4} = 0.0014$

Test of standard 0.01ω copied from legal ohm and made of platinoid strip soldered to copper rods.

No. of Obs.	Time	Deflection on legal ohm	Deflection on copy	Diff.	Mean Diff	Temp.	Value of std. @ temp	Value of copy	Temp. at which current	
1	15.26	658.2	659.5	+1.3						
2	.28	658.0	659.9	+1.9						
3	.31	658.0	660.0	+2.0						
	Batty. + galv. reversed.									
4	.34	655.7	657.8	+2.1						
5	.36	655.8	657.2	+1.4						
6	.39	655.0	656.1	+1.1				$\frac{656.4}{655} \times \frac{40}{100}$		
7	.40	654.3	658.0	+0.7						
8	.43	653.6	653.4	−0.2	1.44	16.5°C.	0.9998	0.9982×10^{-2}	about 108°C.	
9	.45		653.5	−0.5				$= 0.000982$		
10	.47	651.0								
11	.49		653.0	+3.0						
12	.50	650.0								
13	.51		651.8	+1.5						
14	.52	650.3								
15	.53		651.2	+2.0						
16	.54	649.2								

Test of the conductivity of a 10-foot copper rod ½" diam.:
The ends were bent at right angles and inserted in mercury cups. Wire connections were made near the ends and at a distance apart of 269 cms. The mean diameter was 0.25".

No. of Obs.	Time	Deflection on 0.1ω	Deflection on rod.	Diff.	Mean Diff	Value of 0.1ω	Value of rod @ Temp. of rod	Dimensions	Spec. resist. @ temp	% Conductivity
1	17.40	334.4	342	+5.6				$l = 269$		
2	.46	335.3	350.9	+5.6				$r = 0.3187$	1686 @ 17°C.	
3	.48	334.6	339.8	+5.2		0.0999Ω		$r^2 = .0101155$		
	Reversed Batty. + Galv. reversed				+4.7	17.9°C	0.001421	$r^4 = .031191$	1579 @ 0°C.	100%
4	.50	329.9	333.5	+3.6						
		329.4	333.5	+4.1						

Conductivity measurement of a ½" copper rod taken from the Stock Room 8th & 9th February.

Compared rod by deflection test with 0·1 Ag. Ohm by shunting latter with 700 ohm and taking 10 to the galv.

Diam. of rod 0·251" = 0·6373 cms. Length between knife edges 255·7 cms. This length @ 20·6° c. (min) just balanced the shunted legal ohm (21·2°c)

Length Rod	Area	Res. of 5ft @ temp	Multiplying Power	Res. of rod @ temp	sp. res. @ 20.6°C	sp. res @ 0°C.	Standard Conductivity	% Cond.			
255·7	0·3187	0·10008	7·28	0·0011403 = 1·1403×10⁻³	1749	1612	1584	98·3			

Compared with this rod a certain alloy bar of composition brass. Obtained from Messrs Bergmann & Co through Mr Wire.

Dimensions @ follows. Mean length between knife edges 44·7
" breadth of 7 measurements 2·058
" thickness " 1·239

Established deflection balance between 43·8 cms between knife edges of the rod. temp. 20·1°c.

Length Rod	Res. of this length	Length bar	Area	sp. res. @20°c	% Conductivity of brass alloy	% Conductivity of pure copper					
44·7	2·403×10⁻³	44·7	2·5446	1369×10⁻⁶	1722×10⁻⁶	12·6%					

A second test of this made on a previous date as a preliminary measurement and not so close a determination gave the equivalent length of copper rod above measured as 46·5 cms to 44·0 cms between knife edges on brass alloy bar — practically the same results.

Meter Test.

Took the weight of pair of Nickel plates that have been standing for a month on the shelf, with the view of finding the relative hydration gain.

Plate No	Date of preparation	Solution density	Quality of water	plates	Weight of Simply	Weight of Simply 6.2.89	Gain	Gain per Gram	Remark		
1	7.1.89	1.0514	Infusorio	amalgamated but not heated	124·7490	124·7548	0·0058	0·0219	All plates		
2					115·2500	115·2561	0·0061				
					239·9990	240·0109					
3	7.1.89	1.105	"	"	116·8850	116·8902	0·0052	0·0076			
4					116·0730	116·0754	0·0024		on backs		
					232·9580	232·9656			and rim		
5	7.1.89	1.152	"	"	114·4925	114·4859	−0·0066	−0·0030	cost 5% Hg		
6					115·8690	115·8726	+0·0036				
					230·3615	230·3585					
7	7.1.89	1.216	"	"	119·3860	119·3934	+0·0074	0·0130			
8					124·0170	124·0246	+0·0076				
					243·3330	243·3440					
1a	5.1.89	1.0514	"	"	111·2025	111·0750	−0·1275	−0·3188			
2a					120·1690	120·0947	−0·0743				
					231·3905	231·1717					

Measurements with Absolute Electrometer 16th Feby 89

Initial sighted position of disk screw when jar discharged 0·02114 mean of 6
After charging jar by means of influence machine 0·3 gr
corresponds to

	1·4327
Set position	1·40541

Earth reading of this charge 12·47 on micrometer screw
$= 12.47 \times 0.02 \times 2.54 = 0.634$ cm.

The potential corresponding to this is

$$0.634 \sqrt{\frac{8 \times 3.1416 \times 0.3 \times 980}{(2.2575)^2 \times 3.1416}} = 0.634 \sqrt{1347 \times 0.3}$$

$$= 0.634 \times 39.2 \times 0.550 = 12.67$$

$= 420$ volts.

Took the 113 volt circuit and grounded one side of it.

Earth Reading		Dynamo Reading	
12·43		1203	
12·48		1218	
1250		1213	
1240		1202	
1245		1211	
1252		1215	
1250		1216	Mean 1210
1248	Mean 1247		

Difference ·37

P.D ∴ $= 0.37 \times 0.0508 \times \frac{39.2 \times 0.550}{2.536} =$ ~~[illegible]~~ abs: st units 0·4053
$= 12.5$ volts.

Took the 1500 volt circuit and took the potential of each terminal

Earth Reading		Dynamo Reading	
1259		1481	
1267		1493	
1256		1479	
1259		1482	
1263	Mean 1260		Mean 1481

Difference 221

1257		1031	
1262		1024	
1251		1029	
1254	Mean 1256	1033	Mean 1029

Difference 2·27

	4·52

P.D ∴ $4.52 \times 0.0508 \times 24.56 = 4.958$ abs: e. units
14·85 by 1490 volts.

Repeated measurement with 0·1 gramme force on disk follows:-

Initial position	0·02114
0·2 gramme	0·96943
Set disk screw at	0·99057

	Earth reading		Dynamo reading	
Right hand	1807		1489	
	1822		1501	
	1807		1505	
	1791		1490	
	1812	Mean 1809 Difference 319	1484	Mean 1490

Left hand	1805		2110	
	1786		2118	
	1799		2103	
	1795		2113	
	1796	Mean 1796 Difference 316	2114	Mean 2112
				622

PD $6.22 \times 0.0508 \times 39.2 \times 0.447 = 5.538$ abs: e. units
$= 1660$ volts.

Computations 21st March 1911

$t = \frac{R_c C}{R} \log_e \frac{V_0}{V_t} \times 2.3026$

$\frac{4}{3}\pi r^3 \sigma = 28.7$ gms. If $\sigma = 7.8$

$\frac{4}{3} \times 3.142 \times 7.8 \times r^3 = 28.7$ $\quad r^3 = \frac{3 \times 28.7}{4 \times 24.52} = \frac{28.7 \times 3}{98.08} = 0.2926 \times 3 \quad r^3 = 0.8778$

$r = 0.9575$ cm. $\quad d = 1.9150$ cm $= 0.754''$

Assuming the diameter at just $0.75''$ = 1.905 cm. $\quad r = 0.9525$ cm.

$r^3 = 0.86416, \quad \sigma = \frac{28.7 \times 3}{4\pi\, r^3} = \frac{86.1}{12.566 \times 0.86416} = \frac{86.1}{10.859} = 7.928$

Assuming $T \propto t$, we have in the series at the foot of the next page:-

Trial No	Drop Inches	Drop cms.	Full Deflection	Deflection after disp	$\frac{V}{V_0}$	$\log_e \frac{V}{V_0}$	Time sec.	Mean Time	Mean $\frac{T}{L}$	$\frac{T}{L}$
1	14.563	36.99	251	203	1.2364	0.212150	1.9×10^{-4}	300	56.53	56.53 29.52
3	10.0	25.4	278	220	1.2636	0.101622	1.0	"	69.26	69.26 36.17
4	6.0	15.24	278	222	1.2522	0.09769	-	-	66.57	66.29 34.62
5	"	-	278	198	1.5618	0.19362	-	-	80.00	80.00
6	-	-	278	219	1.2692	0.10353	-	-	70.57	70.57 36.85
7	2.0	5.08	278	219	1.2692	0.10353	-	-	70.57	

Sink and mercury

Resistance of 5th Table astatic Galvanometer with all four coils in multiple arc.

Temp Bridge	Bridge	Reading	Lead	Res.	Temp. the coil in temp	Temp. Galvo	Res. at 0°C calculated	Date
18.7°	1000/100 1Ω Lab.	485.2	0.38	484.82	484.9	18.2°	452.25	16.2.89

20th February Wednesday

Sent down to the Phonograph Factory in accordance with instructions 14 oz. of platinoid wire No. 26 B.W.G. 0.018" having a res. of 16 % to the ohm.

21st February Thursday.

Took one of the Bergmann 100,000 ω boxes apart and as they were in B.A. ohms and 1 % short for usual requirement added to each about some 75 feet of no. 35 BWG 0.005" wire G.S. silk covered having a res. of 5.7 ω per foot.

After completion the box tested as follows:

Coil No	Obtd res	Coil to Temp Bridge	Bridge etc.	Temp at which coil correct.	Temp. of box obtd.	Total Res. @ 19.5°	Total Res. @20°C.	
1	25020	25010	100/1000 20°C.	18.5°C	19.5°C.	99945 ω	99965 ω	
2	24981	24970		23.5°				
3	24998	24990		20.5°				
4	24985	24975		22°C.				

Made a series of measurements of the coefficient of self induction in some coils by Rimington & Arkemp method. From these it would seem that the coefficient of load for the 0.04 decomutator is 0.03. The Ratio of the handle and commutator angular velocities is 2.143 ($\frac{4}{7}$) and 6 respectively for the low and high speed.

22nd February Friday

Took a series of measurements of the time of impact between a falling sphere and an anvil as follows:-

The anvil had it upper hardened surface channel and was tilted in such a manner as to throw the ball from it after first impact.

The first ball was of steel its diameter was 0.75" and its weight 28.7 grammes.

Trial No	Drop Inches	Drop Cms.	Full Deflect	Deflect after disp	$\log \frac{V}{V_0}$	Bounces	Duration of impact	Res in set	
1	14 3/4	36.9	251	205 / 201 } 203	0.0217	0.9	5.7×10^{-5}	0.0003 ω	
2	-	-	.						
3	10"	25.4	278	220 / 220 } 220	0.10162	1.0	7.0×10^{-5}	"	
4	"	"	"				6.8×10^{-5}		
5	6"	15.24	278	235 / 178 } 198	0.0977 / 0.19362	"	13.0×10^{-5}	"	Full Curve on mirror. No double jerk
6	"	"		219 } 219					
7	2"	5.08	278	218 / 220 } 219	0.10360	"	7.1×10^{-5}	"	

From this series it would appear that the duration is independent of the height.

Impact Experiments, contd:

t	No.	Metal	Diam.	Mass.	Drop.	Full deal.	Rest after deal.	log ξ	Coefficient φ	Res. Ω	Tuning frequency	Mean	Gen. mean
37.79	1	Steel	1" = 2.54cm	67.01g.	2" = 5cm.	27½	19.8	0.1143	1†	0.0003	9.88×10^{-2}	9.6	
	2					27.5	18.8	0.249	1†	0.00015	9.3×10^{-2}		
30.45	3		3⅜ = 9.7		3⅜ = 9.7	-	15.2	0.257	"	"	8.9	8.75	
	4				" "		15.5	0.249	"	"	8.6		
33.07	5				6¾ = 17.3		15.6	0.246	"	"	8.5	8.14	8.8
	6				" "		15.8	0.241	"	"	8.3		
31.89	7				10 25.4		15.7	0.243	"	"	8.4	8.1	
	8				" "		16.3	0.227	-	-	7.8		
36.41	9				2" 5.1		14.5	0.278	"	-	9.6	9.3	
	10				" "		15.1	0.260	-	"	9.0		
38.58	11		½" 1.27	7.8	2" = 5.1	27½	19.8	0.1143	1†	0.00015	4.9×10^{-2}	4.9	
	12				" "	-	19.8	0.1143	-	-	4.9		
34.46	13				3⅜ = 9.7		20.5	0.1128	-	-	4.4	4.4	
30.71	14				10" = 25.4		21.2	0.113	-	-	3.9	3.9	
40.25	15		½" = 0.635	1.3 g.	3" = 7.6	27½	23.15	0.073	1†	0.00015	2.5×10^{-2}	2.55	
	16						23.1	0.074			2.6		
33.07	17				6" = 15.2	*	22.2	0.091		0.0001	2.1×10^{-2}	2.1	
	18						22.2	0.091			2.1		
31.49	19				10" 25.4		22.5	0.086		0.0001	2.0×10^{-2}	2.0	
	20						22.5	0.086			2.0×10^{-2}		
47.24	21	Copper	1" = 2.54	75g	2" = 5.1	27½	8.5	0.508	1†	0.0001	11.7×10^{-2}	12.0	
	22				" "		8.0	0.538			12.3		
41.73	23				6" = 15.2		9.6	0.465			10.5	10.6	
	24				" "		9.8	0.469			10.8		
	25				" "		9.6	0.455			10.5		11.1
41.73	26				10" = 25.4		9.3	0.469			10.8	10.6	
	27				" "		10.0	0.438			10.1		
	28				" "		9.3	0.469			10.8		
42.0	29		⅜" = 1.9	31.7	2" = 5.1		12.0	0.339			7.8	8.0	
	30				" "		12.2	0.351			8.1		
40.41	31				6" = 15.2		12.7	0.334			7.7	7.7	
	32				" "		12.8	0.331			7.6		
38.85	33				10" = 25.4		12.6	0.337			7.8	7.4	
	34				" "		13.6	0.304			7.0		
	35				" "		13.2	0.317			7.3		

* Reversed small wire to observe whether any contact e.m.f. between the copper and steel at point of contact introduced any effect.

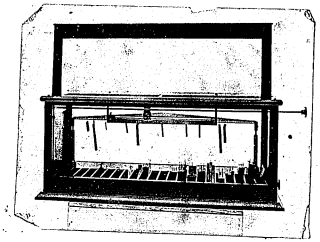
Impact Experiments contd:

No. of Fall	Metal of Plate	Diam.	Mass	Drop	Fall in inch	Per Capacity	Recovery Rebound	Eng. ft	Time	
1	Copper	$\frac{1}{2}$" = 1.27	9. grams	2" = 5.1	274	0.00014 ft	151	1.259	5.97×10^{-5}	5.8×10^{-5}
2				2" = 5.1		0.00014 ft	157	0.2241	5.6×10^{-5}	
3				2" = 5.1		0.00001 ft	10	1.246	23.46×10^{-5}	
4				2" = 5.1		0.00001 "	8	1.574	0.38×10^{-5}	
5				6" = 15.2		0.00001 "	6	1.460	0.38×10^{-5}	
6				6" = 15.2		0.00010 "	94	0.125	5.3×10^{-5}	
7				6" = 15.2		0.00015 "	166	0.215	5.0×10^{-5}	5.3×10^{-5}
8				6" = 15.2		0.00015 "	189	0.161	7.8×10^{-5}	
9				6" = 15.2		0.00020 "	212	0.111	5.1×10^{-5}	
10				10" = 25.4		0.00001 "	58	0.714	?	
11				10" = 25.4		0.00001 "	0	∞		
12				10" = 25.4		0.00001 "	55	0.697	?	
13				10" = 25.4		0.00005 "	105	0.417	4.8×10^{-5}	4.9×10^{-5}
14				10" = 25.4		0.0001 "	168	0.212	4.9×10^{-5}	
15				10" = 25.4	274	0.00015 "	196	0.1145	5.0×10^{-5}	
1	Copper	$\frac{1}{2}$"	0.68	1.35 gr	274	1 ft 0.00015 a	222	0.091	3.2×10^{-5}	3.2×10^{-5}
2				2" = 5.1		0.0001	206	0.126	2.9×10^{-5}	
3				2" = 5.1		0.00005	141	0.288	3.3×10^{-5}	
4				6" = 15.2		0.00005	158	0.238	2.7×10^{-5}	2.9×10^{-5}
5				6" = 15.2		0.0001	206	0.123	2.8×10^{-5}	
6				6" = 15.2		0.00015	223	0.089	3.1×10^{-5}	
7				10" = 25.4		0.00015	231	0.073	2.5×10^{-5}	2.4×10^{-5}
8				10" = 25.4		0.00015	236	0.0644	2.2×10^{-5}	
9				10" = 25.4		0.0007	255	0.030	?	
10				10" = 25.4		0.00005	166	0.219	?	
11				10" = 25.4		0.00001	8		?	
1	Zinc	1" = 2.54	61.5 gr.	2" = 5.1	277	1 ft 0.00001	5			
2						0.00001	10			
3						0.0001	72	0.585	13.5×10^{-5}	13.9×10^{-5}
4						0.0002	135	0.312	14.4×10^{-5}	
5						0.0003	176	0.197	13.6×10^{-5}	
6				6" = 15.2		0.0003	186	0.143	9.9×10^{-5}	
7				(		0.0003	186	0.143	9.9×10^{-5}	9.7×10^{-5}
8						0.0002	152	0.160	7.4×10^{-5}	
9						0.0001	86	0.588	11.7×10^{-5}	
10				10" = 25.4		0.0001	81	0.534	12.3×10^{-5}	
11						0.00002	155	0.252	11.6×10^{-5}	12.2×10^{-5}
12						0.0003	189	0.166	11.8×10^{-5}	
13						0.00004	197.5	0.1146	13.4×10^{-5}	

Gen. Mean 11.9

Meteorological Record.

Date	Tenths	Barometer Reading In.	Barometer Reading Cms.	Temp of Barom.	Bar. red. to 32°	Max. Temp.	Min. Temp.	Thermometer Standing at Dry	Wet	Rainfall last 24 hrs.	Cloud	Wind	Weather & Rain
Mar 1st	Noon	30.378	77.17	71°	30.241	55°	26°	40°		0.18	Nimbus		Overcast
2nd	+ 14	30.242	76.81	72°	30.122	64°	29°	43°		0.	Nimbus	0	Overcast
3rd		30.010	76.23	70°	29.996	45	33	42		0.08	Nimbus	0.08	"
4th		29.636	75.28	63°	29.543	44	33	40		0.51	Nimbus	0	Rain
5th	+ 14	29.412	74.72	70°	29.298	44	37	44		0.50	Nimbus	N fresh	Rain
6th	+ 14	29.158	74.07	68°	29.050	47	33	44°		0.	Cirrus	N fresh	Clear + Tem
7th		29.820	75.77	71°	29.693	50	35	43°		0.	Cirrus	N fresh	Fine
8th	+ 14	29.406	74.69	71°	29.289	54	31	40		0	Cumulus	W. fresh	Fair
9th	+12	29.551	75.06	67°	29.443	42	30	35°		0	Cumulus	W. fresh	Overcast
10th		29.648	75.22	60°	29.560	38	30	37		0	Cirro cumul.	W.	"
11th	+ 12	29.820	75.73	66°	29.738	39	29	37		0	Clear	N	Fine
12th		29.910	75.97	73°	29.787	52	37	46		0	Clear	N	Fine
13th	+18	29.916	75.99	81°	29.769	62	29	56		0	Clear		Fine
14th	+22	30.220	76.78	70°	30.079	70	36	41		0	Clear		Fine
15th	+22	30.006	76.24	68°	29.898	57	32	40		0	Nimbus	E mod.	Overcast
16th		29.740	75.55	71	29.623	51	36	51		0.01	Cirro cumul.	E	Fair
17th		29.704	75.46	60	29.660	55	37	55		0.23	Nimbus		Overcast
18th		29.792	75.68	71	29.675					0.			
19th		29.736	75.54	70°	29.622	60°	35	47		0.	Nimbus		Overcast
20		29.662	75.35	71	29.565	75°	35°	71°		0.05			
21st		29.750	75.56	72°	29.630	40°	34°	39°		0.65	Cirrus		Fine
22nd		30.284	76.42	73°	29.961	46°	35°	46°		0.40	Cirrus	E	Fine
23rd		30.022	76.26	80°	29.978	70°	31°	52°		—	Clear	Light W.	Fine
24th		29.720	~~74.78~~	70°	29.706	77	39	77		—			
25th		29.520	74.98	70°	29.406	54	39	52		—			
26th		29.			29.652	64	41	64		—			
27th		29.904	75.95	76°	29.772	54	27	52		—			
28th		29.754	75.58	77°	29.619	63	29	40		0.1	Rain		
29th		29.930	76.03	73°	29.807	48°	27°	48		0.01			Fine
30th		30.240	76.81	71°	30.123	60	25	34		0.02	Clear	Fresh N.W.	Fine
31st		29.938	76.01	69°	29.857	52	26	36		0.15	Nimbus		Snow mixt.
Apr 1st		29.754	75.57	66°	29.602	42	35	42		0.05			Rain
2nd		29.616	75.25	71°	29.579	51	36	49		0.70			Overcast
3rd		29.808	75.69	75°	29.764	50	34	50		0.0			
4th		29.828	75.77	70°	29.714	68	39	50		0.0	Cumulus		Fine
5th		29.956	76.10	75°	29.827	53	29	49		0.0	Nimbus		Fair
6th		30.116	76.49	65°	30.015	63	32	47		0	Nimbus		
7th		30.222	76.78	52	29.162	48	33	33		0			
8th		30.050	76.32	66°	29.948	60	31	52		0			
9th		29.790	75.68	70	29.676	71	37	59		0	Clear	Light E.	Fine
10th		29.836	75.79	76°	29.704	67	46	58	47	0	Clear		Fine
11th		29.936	76.00	80°	29.792	73	31	63	50	0	Cloudy		
12th		29.866	75.80	67	29.401	77	53	60	57	0.08	Nimbus		Thunderstorm
13th		29.992	76.18	55	29.925	64	30	51	45	0.	Cirrus		Fine
14th		30.254	76.85	71	30.137	71	31	52	43	0	"		Fine
15th		30.230	76.83	73	30.127	62	35°	51	43	0			
16th		29.976	76.14	69°	29.868	58	41	52	50	0	Nimbus	N E strong	Rain
17th		29.906	75.96	71°	29.787	61	51	60	57	0.06			
18th		29.972	76.13	75°	29.843	80	47	76	61	0	Clear	"	Fine
19th		29.906	75.96	69°	29.822	92	52	70	64	0	Cloudy		
20th		29.708	75.46	66°	29.600	75	57	74	60	0.22	Cirrocum.	N fresh	Fine
21								62	42	0.			
22nd						67	30	60	51	0			
23rd						73	36	72	60	0			
24th								76	66	0			
25th		29.892	75.93	74°	29.766	81	47			0			
26th		29.604	75.2	65°	29.505	80	56	59	57	1.53			
27th		29.226	74.24	70°	29.112	61	55	56	55	2.69			
28		29.338	74.53	76°	29.206	56	56	58	53	0.19			
29th		29.450	74.80	66°	29.348	66	48	61	54	0.03			
30th		29.550	75.06	68°	29.442					0.10			



Main Calculator Determinations.

The following are the dimensions of the beam of aluminium.

Total length 66 mm (26").
Central Breadth 3.4 Breadth at extremities 1.0
Thickness 0.097" = 0.025. Thickness of upper thatch plate 0.022" = 0.06
Width of slit 0.3 Length 34.4
Width of thatch plate central 1.5 at extremities 1.00.
Weight of beam. 100 gms.
Safe experimental load 5000 gms.
Weight (experimentally) necessary at one end to balance beam when knife edge hard up 105 gms. 24 ozs for the thatch to the beam.

Specific gravity of a sample of sheet brass.
Strip Length 8.8 breadth 4.3 thickness 0.1475. Volume 17.97
Weight in air 144.8·36 gms. Density (mm vol.) 8.256.
Weight in Lab water @ 12.5°C 130.82 gms. Loss 17.54 sp g. 8.4856
Density of brass by table. Scovill Mfg. co. 8.22 anthony & Brackett 8.4.

From the map of the Brooklyn district it would seem that the greatest number of lamps (likely) to be between any two feeder points is 1000 and equating this to the safe load of the beam each light becomes 5 ~~with~~ grammes.

Beneath the beam there are 22 pockets 4 1/2" × 1" × 1 1/2" deep for weights

No. of lamps represented	~~Weight~~ Grams	Vol. c.c.	Vol. c.in.	Thickness of brass plate in.	Area Sq. in.	Breadth in	Length in.	Nearest simple fraction	No: in pocket	No. of weights
1	5	0.595	0.0363"	0.025"	0.290	0.5"	0.58"	9/16	38	3
2	10	1.190	0.073		0.581		1.16	1 1/16		4
3	15	1.785	0.119		0.870		1.74	1 3/4		5
4	20	2.380	0.145		1.162		2.32	2 5/16		5
5	25	2.975	0.182	0.25	0.726		1.45	1 7/16	18	5
6	30	3.570	0.218		0.871		1.74	1 3/4		5
7	35	4.166	0.254		1.016		2.03	2 1/4		5
8	40	4.760	0.290		1.162		2.32	2 5/16		5
9	45	5.355	0.327		1.307		2.85	2 7/8		5
10	50	5.951	0.363		1.452	1.0"	1.45	1 1/2		5
12	60	7.140	0.436		1.742		1.74	1 3/4		5
15	75	8.925	0.545		2.178		2.18	2 3/16		5
20	100	11.905	0.726		2.904		2.90	2 7/8		10
25	125	14.875	0.908	0.375	2.420		2.42	2 7/16	12	10
30	150	17.853	1.089		2.90		2.90	2 7/16		5
40	200	23.810	1.452		3.87		3.87	3 7/8		5
50	250	29.75	1.815		4.84	2.0"	2.42	2 7/16	4	5
60	300	35.70	2.178		5.81		2.91	2 7/16		2
70	350	41.66	2.541		6.78		3.39	3 3/8		2
80	400	47.60	2.904		7.75		3.88	3 7/8		2
90	450	53.65	3.267		8.71	2.5"	3.48	3 1/2	9	1
100	500	59.51	3.630		9.68		3.87	3 7/8		1
										100

Record of some experiments on the electrocide of animals made on the 12th March, for the New York State Commission.

Preliminary determination of Gardner Voltmeter Constant.

Angular Deflection	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°	130°
Volts	50	60	65	70	78	84	90	96	102	107.5	113	119.5
Corresponding Mean Alty Voltage	45	54	58.5	64	70	75.5	81	86	92	96.7	102	107.5

Res: of Gardner 465 Res: of wire in cct 2200 Multiplying power 14.33

1st A white half spitz dog weighing 21½ lbs: res: 2700 Ω.
Electrodes bandages of waste dipped in hot Zn SO4 sol. density 1.1
Voltage 100° Gardner = 92 × 8 = 736 Time 10 seconds
Dog protruded tongue during application of current but never moved when current off. No sound nor gasp, nor heart action.

2nd A black newfoundland dog Wt 8½ lbs: res 2200
Hair on forehead clipped felt electrodes 4" × 6½" soaked in Zn SO4 bid on forehead after thoroughly wetting skin. Bandage of waste on right hind leg above knee.
Voltage 110° Gardner = 96.7 × = 773.6 Time 15 seconds.
Dog rigid during application and never stirred afterwards.
No sounds gasps or heart action.

3rd Mongrel liver colored. weight 60 lbs. res. 1000 Ω.
Contact back of neck with ~~same~~ larger felt electrodes 9" × 12" and over heart under axilla with smaller electrode 4½" × 6".
Voltage 85 = 83 × 8 = 664 Time 10 second.
Dog made several gasps after removal of current and showed signs of recovery. Evidence of current passing over skin through wet hair owing to large electrode so wet and so close. Singeing of hair audible. Safety catch carried away.
Repeated voltage 70° = 75.5 × 8 = 604 Time 10 seconds.
Same singeing of hair between electrodes and safety catch nearly melted. Dog not quite dead.
Removal electrode from axilla to a bandage round ~~left~~ right hind leg above knee.
Voltage 80° = 81 × 8 = 648 Time 10"
Res: after death 250 Ω.

4th Brown small mongrel weight 35 lbs. res: 500 Ω.
Contact on forehead with small felt electrode and a waste bandage on the right hind leg above knee.
Res: 500 Ω.
Voltage 50° = 64 × 8 = 512 Time 10"
No sound gasp or heart action after removal of current.

5th Calf weighing 74 lbs: res: 500 Ω.
Electrode on right hind leg with wetted waste.
and smaller felt electrode on back of neck.
Voltage 90° = 86 × 8 = 688 Time 15".
Calf not quite dead when current off. Repeated application
Voltage 70° = 75.5 × 8 = 604 Time 15"
Calf quite dead on removal of current.

6th Calf weighing 100½ lbs. res: 550 Ω before + 280 Ω after death
Smaller felt electrode on forehead. and compress on right hind leg.
Voltage 104° = 94 × 8 = 752 Time 20"
Calf quite dead on removal of current.

Electrocide experiments contd:

7th Calf weighing 98 lbs. Res: 3140 w. after death 230 w.
Contact on back of neck with smaller felt electrode and right fore leg.
Voltage 105° = 95 × 8 = 760 Time 15".
Result no shock gait or heart action when current off.

8th Calf weighing 109 lbs. Res. 380 w. of
Contact right fore leg and left hind leg. wall compressed
Voltage 100° = 92 × 8 736 Time 15"
Calf not quite dead, slight attempts at gasping.
Repeated 70° = 75.5 × 8 604 Time 20".
Quite fatal.

9th A brown horse weighing 830 lbs. res: 500 w after death 200
Contact on forehead with small electrode and on left hind leg above knee with large electrode.
~~Voltage~~ Fore feet and hind feet hobbled - Horse fell.
Voltage 90° = 86 × 11 = 946 Time 25".
Horse rigid during application of current and after removal, no heart action or sign of life visible.
Repeated application of current to observe effect. The spasm equally great both on hind + fore legs

The low resistances observed in all these cases were measured with a Siemens Universal galvanometer and are attributable to the ~~hot~~ zinc sulphate solution which was kept hot all the time.

Present Mr H. P. Brown, Dr MacDonald
The Demonstrator of Physiology in the University of Penna
Two other surgeons, and a gentleman from the Albany commission office.

log 0.00388 = 0.0016628
×23.8 = 0.0400050

log 9.528 = 0.97900
0.04005
1.01905

log 9.662 = 0.98507
0.02395
1.02512

Some Data in Connection with the Brooklyn Electrical Determination of the Underground System.

The voltage of the lamps being stated as 115, + the drop in the main as 1% makes the pressure at the feeder terminal 116.16 (say 116.2) and at 12% drop in the feeder = 132 volts
" 10% " " " " = 129.17 " say 129.2

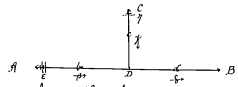
Taking 1 mil foot as = 9.718 B.A. units at 0° C = 10.664 B.A.U. @ 75°F = 26°C
= 10.548 Legal U. @ 24°C

This is the value for 100% conductivity.
Taking the commercial copper as 97% conductivity, this becomes
= 10.868 legal ohms @ 24°C

On the basis of the tables in Everett's work the sp. res. of annealed copper in legal ohm is given at 15844.00. One foot of copper would thus be 30.48 × 15844 = 48280 ohm. U. one inch diam. has an area of 0.7854 sq. in. = 7854 × 6.4516 = 5.0671 sq. cms. Therefore a one inch rod or 1000000 circular mil would have a res. of 9.528 legal U @ 0°C.
or 1 " " foot " " " " 9.528 legal " .
10.145 " @ 24°C

On the basis of a statement in the same work that a wire 1 mm long 1 mm diam has a resistance of 0.0[illegible] Ω. 1 foot long would be 0.0[illegible] = and 1 mil in diam would be 9.662 leg. Ω @ 0°C. = 10.596 " legal @ 75°F
Taking the first reckoning of 10.868 @ 24°C as standard we have

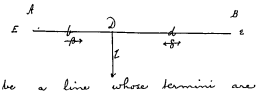
S.G.N.	Circular Mils	Res. per foot	S.G.N.	Circular Mil	Res. per foot	Conductivity per foot	S.G.N.	Circular Mil	Conductivity per foot
3	3000	0.003623	220	220,000	0.000004940	20,260	3	3000	276
5	5000	0.002,1736	240	240,000	0.000004529	22,080	5	5000	460
8	8000	0.001,3585	260	260,000	0.000004180	23,920	8	8000	736
12	12,000	0.000,9069	280	280,000	0.000003881	25,760	12	12,000	1104
15	15000	0.000,7245	300	300,000	0.000003623	27,600	15	15,000	1380
20	20,000	0.000,5225	320	320,000	0.000003396	29,440	20	20,000	1840
25	25,000	0.000,4347	340	340,000	0.000003196	31,280	25	25,000	2300
30	30,000	0.000,3623	360	360,000	0.000003019	33,120	30	30,000	2760
35	35,000	0.000,3105	380	380,000	0.000002860	34,970	35	35,000	3220
40	40,000	0.000,2613	400	400,000	0.000002713	36,810	40	40,000	3680
45	45,000	0.000,2415	425	425,000	0.000002557	39,110	45	45,000	4140
50	50,000	0.000,2174	450	450,000	0.000002415	41,410	50	50,000	4600
55	55,000	0.000,1976	475	475,000	0.000002288	43,710	55	55,000	5060
60	60,000	0.000,1812	500	500,000	0.000002174	46,010	60	60,000	5520
65	65,000	0.000,1671	525	525,000	0.000002070	48,300	65	65,000	5980
70	70,000	0.000,1553	550	550,000	0.000001976	50,610	70	70,000	6440
75	75,000	0.000,1449	575	575,000	0.000001890	52,910	75	75,000	6900
80	80,000	0.000,1307	600	600,000	0.000001812	55,210	80	80,000	7360
85	85,000	0.000,1278					85	85,000	7820
90	90,000	0.000,1208					90	90,000	8280
95	95,000	0.000,1144					95	95,000	8740
100	100,000	0.000,1087					100	100,000	9200
110	110,000	0.000,0988					110	110,000	10,120
120	120,000	0.000,0907					120	120,000	11,040
130	130,000	0.000,0836					130	130,000	11,960
140	140,000	0.000,0776					140	140,000	12,880
150	150,000	0.000,0725					150	150,000	13,800
160	160,000	0.000,0679					160	160,000	14,720
170	170,000	0.000,0639					170	170,000	15,640
180	180,000	0.000,0603					180	180,000	16,560
190	190,000	0.000,0572					190	190,000	17,480
200	200,000	0.000,0522					200	200,000	18,400



If AB be a line through which a current β flows from an EMF ε and if at the point D another current be grafted on it from EMF γ we have the following conditions of current and potential before and after the operation.

	Before	After	Variation
β	$\dfrac{\varepsilon}{b+d}$,	$\dfrac{\varepsilon-\gamma\left(\frac{d}{c+d}\right)}{b+\frac{cd}{c+d}}$,	$-\dfrac{d\left\{\gamma-\varepsilon\frac{d}{b+d}\right\}}{bc+bd+cd}$
δ	$\dfrac{\varepsilon}{b+d}$,	$\dfrac{\varepsilon c+\gamma b}{bc+bd+cd}$,	$+\dfrac{b\left\{\gamma-\varepsilon\frac{d}{b+d}\right\}}{bc+bd+cd}$
pot. @ D	$\dfrac{d\varepsilon}{b+d}$,	$\dfrac{cd\varepsilon+bd\gamma}{bc+bd+cd}$,	$+\dfrac{bd\left\{\varepsilon(c-d)-\gamma(c-d-b)\right\}}{(b+d)(bc+bd+cd)}$

So that if $b=d$, whatever be the res: or emf grafted at D on the main circuit the variations of current strength on each side of D will be equal and opposite.



If A ~~and~~ B be a line whose termini are maintained at potentials E and ε respectively, with the same notation we have

$$\beta = \frac{E(d+l)-\varepsilon l}{bd+bl+dl} \qquad \delta = \frac{\varepsilon(b+l)-El}{bd+bl+dl}$$

So that if we consider the potential difference between E and D before and after the application of the emf ε we have.

Before	After	Variation
$\dfrac{b(Ed+\varepsilon b)}{bd+bl+dl}$	$\dfrac{bE(d+l)-b\varepsilon l}{bd+bl+dl}$	$-\dfrac{b^2\varepsilon-bl(E-\varepsilon)}{bd+bl+dl}$

Meter Experiments contd.

March 28th Thursday)

Took some measurements of the res: and counter e.m.f of a silver voltameter to see how far it would conform to the conditions demanded in an Edison station meter.

Took a strip of silver 21.8 cms long and 3.8 broad, divided it into 5 lengths 10.9 X 3.8. These were flattened, and finally cleaned with dilute acid and caustic potash. They were then fixed opposite each other and 0.5 cms apart. Wires were connected with their upper edges. The plates were then immersed in a solution of $AgNO_3$ that was made up some months ago 25% by weight. Its density under this test was 1.27 and the temperature at the time 23°c.

The beaker in which the plates stood was 13 cms high and 5 in diam.

No.	Strip	Res.	T.Z.	F.Z.	Leads	Counter emf	TZ - FZ	Temp. of solution	Area of surface of anode
1	100/10	1.1	21.00	3.50	0.02	0.018	17.5		
2		2.1	11.8	2.90		0.019	8.9	23°c.	
3		3.0	7.6	2.3		0.017	5.3	Plate 0.5 cms	
4		5.0	5.6	2.1		0.017	3.5	apart	
5		10.0	3.0	1.5		0.015	1.5	Area 29.26	
6		20.0	1.9	1.2		0.014	0.7		72a
7	Preceding day	3.1	14.5	3.0		0.025	8.5		
8		19	2.2	1.14		0.015	0.8		
9		3	10.3	2.7		0.022	7.6		

Hard Rubber Substitute Test

April 8th 1889.

The following tests were made of a sample of black substance intended as a substitute for rubber. Its thickness was 3/8". A sheet of hard rubber 3/8" thick was selected for comparison.

A strip was cut from each sheet, the dimensions being 15 cm X 1.35 X 0.78. In cutting the new material that smelled like ebony had a granular structure and cut off in powder was much softer than the rubber. On taking these strips placed equal and fixing them across blocks of steel, the breaking strain in the center was found to be about 100 lbs for the new material and 115 lbs for rubber which bent much more before fracture.

The spec: gravity of the real hard rubber was 1.18
" " " substitute " 1.38

The weight of two pieces of substitute were 11.09 and 10.78 respectively. After immersion for two hours in a solution of NH_4HO and acetic acid the weights were 11.11 and 10.78.

Weight of the Bipolar Dynamo

Schenectady casting	2720
Compbell "	2470
Steel shaft	170
Bearing	200
pulley	200
rail	150
rocker arm	50
iron wire in armature	460
commutator	100
armature wire	30
woodwork of frame	60
Bobbin wire	500
	7120

say 7200

April 1st Monday. Used small induction coil for preliminary experiment. Its length is 18 cms its diam 2.5. The res. of its primary 0.14 its secondary 7500.

Actuated the primary and its automatic vibrator with the 60 volt dynamo. Connected the secondary terminals to two air condensers formed of two ebonited brass disks each 17.4 cms in diam and separated by about 0.5 of an cm. Next took a spark micrometer whose electrodes are tapering points and joined them by a wire of black covered copper some 150 cms long. Twisted this covered wire round the rods of the air condensers. Ascertained that the sparks passed easily between the points of the micrometer when the distance was perhaps 0.025 cms.

April 2nd Tuesday.

Repeated this experiment with the large induction coil whose length is 51 cms and diam 20. Its primary res. is 0.205 ω and its secondary 31000. Actuated it by a mercury contact breaker using the 100 volt circuit and some 10 to 20 ohms of resistance. Tried to obtain sparks from the micrometer when short circuited as before, but without success. Many combinations were tried but even when considerable self induction was interposed in the short circuiting wire, the spark invariably failed to appear at the micrometer nor could any p.d. be detected by the tongue.

April 3rd Wednesday. Tried experiment again with small coil. When its secondary terminals were connected direct to the terminals of the micrometer no device succeeded in obtaining sparks or p.d. evidences any convenient length. So soon however as the micrometer wires were insulated and laid upon the terminals of the air condenser, sparks were immediately visible, and continued to be distinguished even when short circuiting was effected through thick copper rod. They were however very faint and could only be discerned by selecting the micrometer points. On making two coils in air round the condenser rods the with the micrometer wires these effects were still visible so that conduction under changing the colours of two leyden jars direct from the secondary terminals and taking the intervening to the micrometer these sparks after short circuiting were distinctly increased. Tried the same experiment with the large coil and succeeded in obtaining distinct sparks across an air break of any short length (not permitting a knife edge to intervene) when short circuit made with a wire and a ¼" copper rod passed above the micrometer pillars.

It was observed that when sparks were thus passing freely during this experiment between the micrometer points short circuited by a bare wire 0.1 diam and some 10 cms long, the interposition of an opaque substance such as paper or metal, caused them to cease. Happening however on the removal of the substance. The same effect was produced by interposing a sheet of transparent glass but occasionally a spark would be observed in this case. Various coloured glasses were tried and they all (obstructed apparently) the passage of the spark. Quartz however in the form of a thin section ⊥ to the axis seemed to offer very little obstruction, but another section parallel to the axis seemed to offer some obstruction less than glass.

The micrometer was then fixed in a convenient dark box admitting of a ray of light through a suitable aperture to fall upon the point short circuited as above. By observing through an eyepiece on the same principle as the Ethnoscope, it was evident that a ray passing through a metal aperture 0.5 in diam from the spark between the jars had influence on the passage of the spark at the micrometer when the intervening distance was 80 cms. The closing of this aperture by a side screen instantly stopped the spark and did also the interposition of different kinds of glass, ebonite, tube, mica, and quartz section parallel to the axis. Some

of these substances acted in different degrees, plain glass and talc being perhaps the most effective. An observer watching the sparks could tell the moment one of these substances divided the line between the two, & was noticed that whenever the spark occurred, the tongue applied to the points could detect the electrical disturbance.

Tried whether an incandescent lamp could by its light restore the micrometer spark when this was extinguished by some screen or other but without success. On removing the shutter screen the passage of the incandescent lamp across the spark connecting line extinguished that at the micrometer. Next tried an independent induction coil spark with and without a Leyden jar and tried to effect the reproduction of the extinguished micrometer spark by its aid without success.

Removed the micrometer and dark tube to a distance of about ½ metre from the Leyden jars, but spanning the distance by two cotton covered wire 0·1 diam. At this distance the mutual relation between the sparks was scarcely if at all evident.

Brought the micrometer back to its previous range and tried to substitute an arc light for the jar spark in restoring the lost micrometer spark but at a distance of some 2 metre between arc and micrometer this was not successful.

The only substances found which permitted the mutual action to pass unchecked were quartz sections at 45° to axis and rock salt, the latter even 2 cms thick.

April 4th Thursday

Inserted a powerful solenoid between of 14 layers between the two sparks so that the mutual influence took place through it axis. Excited this powerfully by an alternating current making some 230 complete periods per second. No effect from this alternating magnetic field could be discovered upon the sparking.

Made a small rock salt prism and tried to find at what particular angle of prism rotation the sparking at the micrometer was affected when all the light was cut off except through the rock salt. The prism was however too imperfect to be able to arrive at any conclusion but it certainly did interrupt the sparking contrary to the behavior of plane sections.

Arranged a plane mirror about 5 cms in diam. in such a manner as to reflect the jar spark upon the micrometer points even when the direct spark was cut off from all influence. Unmistakeable evidence of the influence being exerted by the reflected ray, though it may have been a little less decided.

Took a slip of microscope glass and 0·013" = 0·033 cm thick and found that even this thickness effectually stopped the influence, the micrometer spark ceasing on the insertion of the polished slip in the line of action.

April 5th Friday

Repeated last experiment with glass screens 0·005" = 0·011 cm thick. Also tried to ascertain by thin slips of thin glass arranged in different positions whether the effect observed was due to an influence on the dielectric or on the electrodes themselves. It seems from these trials that if the electrodes are screened the influence is cut off but if the air space is screened and the points left within view of the main spark the micrometer spark continued. On removing the short circuiting wire and replacing it by a sounder whose magnetic circuit was forcibly closed so that it possessed large self induction, the spark length was increased to 0·25 cm. At one time it seemed that the screening of one point interrupted the spark more than the screening of the other, the effect reversing with the reversal of the wires from the jars, but other experiments did not always show this. Little or no influence could be obtained by reflection from a thick silvered glass mirror, not in restoring the spark, but a simple

sheet of steel seemed to reflect the influence. A small Bunsen burner flame was thrown round the secondary after the spark had been interrupted by a screen but without success unless the flame were very close above or underneath them.

Took a glass parabolic mirror 33 cm in diam: and of about 20 cm principal focal distance, after a preliminary trial at short range succeeded in obtaining the influence by its means when the distance between the sparks were about 5 metres and the actual distance travelled over by the influence some 7 metres.

Took a second parabolic mirror similar to the above, and placed them facing one another at opposite ends of the galvanometer room some 23 metres apart. In the focus of one was set the primary spark, and at the focus of the other the micrometer point, the distance being spanned by two g.p. Zinc wires rather in excess of length. The micrometer air space was about 0·025 cm and the secondary formed the short circuit. The influence was plainly discernible but was not as complete as at short range. This may have been partly due to the variation of the primary spark from the focus. It appeared as though time were required to stimulate the reproduction of the spark on removing a screen from the line of mirror action, just in the way a spring takes time to respond by increasing amplitude to a continuous stimulus before a maximum is obtained.

April 6th Saturday

Repeated this last experiment with the same general results. Finally returned to the original conditions, forming the primary spark however between two platinum points. Interposed a number of substances to see if any others permitted the passage of the influence. Bladder, Indian skin, Sweat gum, paraffine, &c. Also among the microscopic double refracting disks, calc spar, borax, aragonite, tourmaline and quartz. Of these last there were three and one only out of all the materials tried passed the influence. No indication of the direction of action was found on this disk.

April 9th Monday

Tried the effect of a beam of sunlight upon the restoration of the spark. Simple sunlight did not succeed but sunlight condensed to a focus by a double convex lens succeeded fairly though not markedly. Tried thin sheets of amber and found one or two to be slightly successful. Succeeded in getting good results through a cube of rock salt!

April 9th Tuesday

Tried to see if there were any purely electrical disturbances in the micrometer circuit due to radiant action on the points. Found that galvanometer was disturbed by magnetic influence of induction coil. Used quadrant electrometer and found disturbances on producing primary sparks but from such tests as were made the disturbance appeared to be chiefly electrostatic due to influence of charge upon circuit and not dependent on radiant action.

Succeeded in obtaining results through films of water, solution of methyl violet, aniline brown, oil, glycerine and water, sulphate of copper and weak solution of ferrocyanide of potassium.

April 10th Wednesday

Took two glass rods 0·36 cm diam and about 2·5 long with a platinum wire 0·03 diam fixed throughout their length, and passing out freely at one extremity. The opposing ends were filed flat so that the wire section was flush with the glass surface neither receding nor protruding. These rods were clamped opposite to each other so as to bate the place of the micrometer points. Their distance arrangement was

April 8th, 1910 Test of certain specimens of non-inflammable wire

Received from Mr Insull for testing 5 specimens of wire as follows

#1 No 14 copper wire 0.056" covered to 0.20" dark red + black braid marked
silicate of soda grade 1

#2 No. 14 copper wire 0.056" covered to 0.20" red yellow braid marked
grade 1 non inflammable

#3 No. 14 copper wire 0.056" covered to 0.20" red yellow braid marked grade 2
coating rubber non inflammable

#4 2 strands each 12 # 32 B&S 0.0055" copper rubber covered, and coated with
red and black braid, marked flexible cord non inflammable

#5 2 strands each 14 0.0055" copper rubber covered and helically coated with
steel wire, green and yellow braid marked flexible cord covered
with steel wire.

Specimens of all these samples were tested with bunsen flame and found to be practically non inflammable since any flame set up was soon extinguished on isolation.

Soaking for 5 mins: in water was not found to impair the insulation of any specimens.

On forcing a current through other specimens to the melting point the behavior was as follows

#1 Melted without catching fire
#2 burst into flame on melting at two point
#3 - - - - - - - .
#4 - - - - - .
#5 - - - - -

The current used for the 1st three was about 150 amperes and for the last 2 about 50.

Data concerning Octopolar Dynamo resistance.

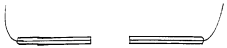
152 Commutator Blocks
456 Turns of no 10 wire @ 5.75×10^{-4} μΩ/20" each = 1.7 ft
8 complete batteries = 57 turns per battery

$57 \times 1.7 \times 5.75 \times 10^{-4}/8 = 69.7 \times 10^{-4} = .00697$
Add to this about 7" equivalent of # 12 wire .0005
Total .0075 ω.

1 h.p. 20 when est: res: .0750 = 746/3.00 lamps @ 200 w each
= 860 amperes.

Assuming that the heat from the forcable current could be reduced 50% the temperature rise would if there were no convection be also only 50% but with convection into account it would be more say 70%.

A glass tube electrode and secondary spark
B primary spark between pt. wire vertical
C secondary terminal of induction coil



Electrical Oscillation Experiment

was as shown. Distance between primary + secondary sparks 10 cm
In the 1st trial with the two glass rods at an angle of 165° and converging towards primary spark. the distance between them being 0.02 cm. the number of sparks passing during 25 primary make and breaks was 50 unscreened and 1 screened.
On making the angle 150° and keeping the same distance the number of unscreened sparks was 47 of screened 2.
On making the angle 143° diverging from the primary spark the number of unscreened sparks was 25 of screened 0.
Cleaned the surfaces of the electrodes and repeated last trial with the distance between them 0.017 and the angle 143½° the number of unscreened sparks 43 and the screened 45.
With the angle of 147° and the same distance the number of unscreened sparks 25 and screened 29.

The platinum wire were then drilled out for a distance of about 0.05 cm with a needle drill, so that they were certain to be screened at their extremities from direct radiation. At a distance of 27 cms from the primary spark the results were :—

No: of contacts	∠ between electrods	Dist: apart	Screened spark	Unscreened sp.
25	180°	0.225 cm	29	38
		0.20 "	11	
		0.15 "	42	44
		0.275 "	12	12

There can thus be no question that the effect observed takes place almost entirely at the surface of the electrodes.

Tried small fragments of the following substances to see if the influence would pass through them. They were held before the ⅛" orifice in the brass shutter. Hard rubber 0.005" camphor iodine scales, soft rubber, animal glue. $Fe\,PO_4$, tartrate of iron, all these failed.

A solution of bichromate of potash as a film upon the orifice stopped the influence, contrary to the behavior of the other aqueous solutions already tried.

Ascertained that a thickness of glass ~~1/5000~~" = 0.00025 cm invariably stopped the influence.

April 11th Thursday

Tried scale or thin crystals of the following substances without success

Cellulose 0.027
Bichromate of potash
Sulphate carbonate
Cinnabar
Mercury methyl chloride
" ethyl "
Tartaric acid $C_4H_6O_6$
Citric acid $C_6H_8O_7$
Boric acid B_2O_3
Iron Borotartrate Fe
Iron Mallic $Fe\,C_4H_4O_5$
Phosphoric acid PO_4
granular
Sodium Metaphosphate $Na\,PO_3$
Potassium phosphate HK_2PO_4
Sodic oxalate $Na_2C_2H_2O_4$
Potassium Tartrate
Potassium ferrocyanide $K_4C_6N_6Fe$
" ferricyanide $K_3C_6N_6Fe$
" sulphate K_2SO_4
" chromate K_2CrO_4
Magnesium nitrate $Mg\,NO_3$
Iron amm. sulphate $Fe_2(NH_4)_2SO_4$
Nickel " " $Ni_2(NH_4)_2SO_4$
Aluminate of potash
Sulphocyanide of guanidin
Sulphur cyetal

Problem. To find the dimensions of a steel rope which should be capable of bearing the gravitating pull exerted between the earth and the sun.

The attractive pull exerted is $F = \frac{cSe}{d^2}$

where S is the sun's mass $= 18 \cdot 42 \times 10^{32}$

e - - earth's $= 6 \cdot 14 \times 10^{27}$

d - - intervening distance $= 1 \cdot 487 \times 10^{13}$

c - - gravitation constant $= 6 \cdot 48 \times 10^{-8}$

$$F = \frac{1 \cdot 842 \times 6 \cdot 14 \times 6 \cdot 48 \times 10^{26}}{1 \cdot 487 \times 1 \cdot 487} = \frac{73 \cdot 3 \times 10^{26}}{2 \cdot 211}$$

$$= 3 \cdot 315 \times 10^{27}$$

The tenacity of steel (low) is stated to be $7 \cdot 93 \times 10^{9}$ so that the area of the rope would have to be

$$\frac{3 \cdot 315}{0 \cdot 793} \times 10^{17} = 4 \cdot 18 \times 10^{17} = 41 \cdot 8 \times 10^{16}$$

The diam $= 7 \cdot 3 \times 10^{8}$ cm. $= 450$ miles.

The steel rope would have to be 450 miles in diameter.

The earths velocity in her orbit being about $2 \cdot 96 \times 10^{6}$ her centrifugal force must be

$$F = \frac{2 \cdot 96 \times 2 \cdot 96 \times 6 \cdot 14 \times 10^{26}}{1 \cdot 487} =$$

$$= 3 \cdot 618 \times 10^{27}$$

The two expressions for F should coincide.

Determination of sp: gr: of certain specimen of transparent mineral sent by Mr Davenport of 81 Howard St Detroit Mich

Weight in air	0·7340 gm	Wt silken cord 0·0005	Tare wt 0·7335
- - distilled water	0·3966	- - - 0·0005	- - 0·3961
			0·3374

Temp. water 21°C. where density 0·998

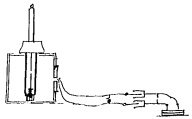
$$\frac{0 \cdot 7335}{0 \cdot 3374} \times 0 \cdot 998 = 2 \cdot 170.$$

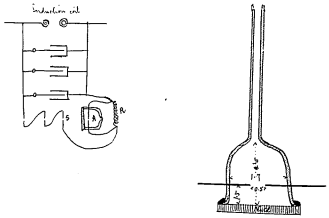
The stone will not scratch sapphire or quartz.

Is slightly yellow, irregular, brittle.

Slightly positive ~~sol~~ electrically when rubbed.

Presumed to be some of the quartz group





Electrical radiance experiment.
Tried the following solutions as droplets held in a hole about $\frac{1}{16}$ square in a glass plate.

Passing influence	Obstructing influence
	$Pt\ Cl_4$
	$K\ NO$
	$(NH_4)Cl$
	$(NH_3)\ H_2O$

Tried sapphire, glycerine, and different qualities of glass, also cassidar balsam also without success. But found that thin films of $Ce\,SO_4$ crystal, mica, and $H_2\,Mg\,O_2$ are just on the dividing line between transmitters and obstructors, thin films allowing the influence to pass more or less readily.

April 12th & 13th

Connected up a flipper arc lamp in the lantern box and closed its lens aperture with a wooden plug in the centre of which a small hole 1·25 cms was left. This hole and the entire plug was blackened. On each side of it was screwed a brass plate with two clamp screws. By means of these clamps, wire could be fixed with their ends at the centre of the hole and at any desired proximity.

Wire of Brass copper lead magnesium solder platinum, cadmium, zinc, tin and iron all it was found that the ignition of the arc at a distance of 18 cms would restore the spark and the interception of the beam stopped it. But the adjustment had in some cases made closely

Ascertained that the influence was transmitted by sections of fluor spar and ammonia alum.

April 14th

Received from Professor Eglatine (Columbia Coll) for Mr Edison 3 quartz prisms and one of Fluor Spar.

By means of these prisms (April 18th) ascertained that the rays which affected the micrometer spark were chiefly confined to the ultra-violet spectrum.

April 19th

Made a dutch metal electroscope and after producing divergence with 500 and also 100 volts, tried to see if insolation directly produced any change but was unable to observe any.

April 20th

Arranged an induction coil as shown. Three leyden jars in its cct. and three primary air sparks together with a rectangular coil of three and three wound on a stem. This coil was charged by an spark distance of 0·5 in a glass chamber A through which walls the platinum wire was sealed. The face of this bell shaped glass chamber was a plate of rock salt 0·4 cm thick sealed on with sealing wax. By means of the glass tube the chamber was connected with the mercury pump and was exhausted. During the process of exhaustion it was observed that with A facing one spark S waves of rosy light ran up the whole length of connection tube (about 100 cms) to the pump. This took place so long as one wire (either) remained connected between A and R but ceased when A and R were totally disconnected. When the vacuum became higher this effect did not take place.

On removing A sparks would traverse occasionally the three breaks S and the resistance R. On connecting A to R it was observed that the passage of a spark at A acting as a short circuit to R greatly strengthened and promoted the sparks at S. The influence usually observed at ordinary atmospheric pressure was here quite discounted as the following observations show together with the remarkable fact that very seldom any sparks at S occurred without spark at A, and consequently the influence of a spark at A set up by a transparent substance not only affected A's spark but also that at S.

List of substances found to be opaque and transparent up to present date in electrical radiance

List of Transparent substances

Rocksalt
quartz
Clear colorless amethyst
ammonia alum
Thin mica, and bruciite.
Water
Ice
Many aqueous solutions of salts

List of Opaque substances

Metals in plates
Carbon
Glass even $\frac{1}{10,000}$". 2.5μ
cellulose
rubber hard soft
canada balsam
Beryl
Tourmaline
Purple amethyst
Aragonite
Celestite
Barium sulphate
Lead carbonate
Camphor
iodine
animal glue
Sale
Solution of $Pt\,Cl_4$ / $K_2\,Fe_2\,C_6$ } in water.
Potash alum.
Agate

Electrical Radiance experiment.

Distance between sparks S and spark A		2.5 cms.	Facing each other
In 25 contacts	air separation only	23 sparks	at A.
- - -	glass 0.1 thick inserted	6 -	- A.
Distance between sparks increased to 7.5 cms.			
In 25 contacts	air separation only	12	
	rocksalt plate in hand	24	
	air	17	
	rocksalt held in hand	20	
	air	18	
	rocksalt held in place	16	
	brass gauge	13	
	air	19	
	copper sheet	8	
	air	11	
	copper sheet	4	
	air	18	
	hard rubber sheet	10	
	air	22	
	hard rubber	11	
	air	25	
	glass plate	10	
	air	20	
	glass	8	
Distance between sparks increased to 16.5 cms			
In 25 contacts	air separation	15	
	rocksalt	12	
	air	10	
	brass gauge	9	
	air	15	
	copper sheet	2 at A	5 at S
	air	14	- - 14 - -
	hard rubber	6	- - 6 - -
	air	11	- - 11 - -
	glass	1	- " 2 - -

Means for

air	rocksalt	brass gauge	copper sheet	rubber sheet
18	20	13	6	11

glass sheet
9

Means: air 13 rocksalt 12 brass gauge 9 copper sheet 2 hard rubber 11 glass 1

23rd April.

Tried a number of different minerals for transmissive power, the specimens having been lent by Prof. Egleston of Columbia College.

Some 50 quartz specimens, sections were tried, and of these only two were found to be opaque. Both were parallel to the axis but one was concave. The other 24 mm square was a brown plate. A small lenticular piece from this was transparent as also was the whole section laterally. The following opaque minerals were found.

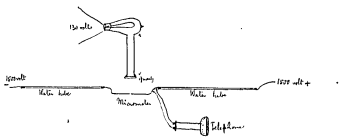
Tourmaline. Clear transparent beryl. Transparent carbonate of lead, Emerald Beryl, Aragonite. Alum. Barium sulphate.

Finding that a section of quartz || axis was transparent, carefully examined the one of the Edison collection already recorded as opaque. Discovered that it was backed by a glass plate cemented with canada Balsam. On removing these the plate was at once transparent. Also two hyperbolic plates of quartz united by canada balsam in the Edison collection were partly separated and cleaned. The separate sections were transparent but where still united by balsam, the pair remained opaque.

Amethyst was found to be transparent when clear and colorless and thicker specimens in a partly colored and partly clear state were transparent to the influence whenever the clear portions were brought over the window.

A small cube (1 cm) of smoky quartz was transparent to influence.

A Primary spark shaded
B - - active + horizontal
C - - shaded
D Passive spark
E Induction coil of ten turns
F Plate of wood held in retort ring
G - - -



Experiment were tried with wire whose extremities were in opposed juxtaposition towards in alcohol and in water a few cms below the active spark. The spark length was much shorter than in air. The difficulty with alcohol were the continual explosions. With water it seemed that when the wire were close up to the surface a slight effect was obtainable, but not sufficiently marked to be certain, but when deeply immersed there was no effect to be detected.

May 3rd Friday. Connected the 1500-volt terminals to the sparking points through two tubes 23" long ½" bore full of tap water with small nickel wire 1" long inserted as electrode. With this arrangement obtained a distinct striking distance between opposed points of about 0.021 cm in air.

Took a Nernst lamp that had a ⅞" glass tube 6" long melted horizontally into the side and closed by a mica plate. With this at 113 volts tried to obtain effect on a passive spark without success.

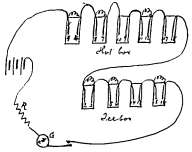
May 4th Saturday

Took another lamp fitted with the same tube and used the 130 volt circuit for its supply. When this was fixed so that the rays were thrown vertically down upon the points connected with the 1500 volt circuit a distinct effect could be obtained. That is to say sparks would break across under the influence of the light when they ceased altogether during the removal. The same effect was produced with the spark from the induction coil.

Finally inserted a telephone in the 1500 volt circuit and when the points were at such a distance that no sparks were heard to pass but just so that a very small motion of the screw would allow their passage, on lighting the lamp they were immediately audible, and the usual effects of rock salt rubber etc. were also recognized.

Meteorological Record.

Date	Time	Barometer Reading Inches	Corrs.	Temper. of Barom.	Barom. reduced to 32° F.	Thermometer Max.	Min.	Thermometer exposed at Dry	Wet	Rainfall last 24 hr.	Clouds	Wind	Weather Remarks
May 1st	Noon	29.834	75.79	73°	29.705	63°	38°	61°	52°	—	—		Fine
" 2nd	"	29.784	75.66	74°	29.659	63°	39°	52°	45°	—			Fine
" 3rd	"	29.834	75.78	67°	29.759	72°	30°	67°	57°	—			Fine
" 4th	"	29.900	75.93	75°	29.771	66°	40°	66°	54°	—	—	East	Fine & fog
" 5th	"	29.932	76.03	81°	29.795	80°	47°	78°	67°	—	—	"	Fine
" 6th	"	29.938	76.04	74°	29.800	90°	49°	82°	58°	—	—	"	Fine
" 7th	"	29.946	76.05	77°	29.811	91°	46°	80°	68°	—	—	"	Fine
" 8th	"	29.806	75.84	74°	29.680	93°	49°	84°	72°	—	—	"	Fine
" 9th	"	29.504	75.04	80°	29.391	100°	60°	93°	72°	—	—	West	Fine
" 10th	"	29.820	75.88	75°	29.727	79°	46°	79	68°	.013	—	West	Fair
" 11th	"	29.764	75.60	81°	29.617	86°	55°	83°	69°	—	—	West	Fair
" 12th	"	29.816	75.74	70°	29.702	80°	54°	70°	66°	—	—	East	Fair
" 13th	"	29.634	75.40	78°	29.546	80°	60°	68°	65°	0.06	—	West	Overcast
" 14th	"	29.838	75.91	72°	29.766	90°	62°	84°	70°	—	—	West	Fair
" 15th	"	29.970	76.13	73°	29.867	96°	52°	84°	76	—	—	South	Fair
" 16th	"	30.240	76.81	75°	30.111	96°	51°	90°	84°	—	—		Fine
" 17th	"	30.196	76.71	78°	30.058	96°	64°	86°	79°	—	—	South	Fine
" 18th	"	30.135	76.61	71°	30.038	92°	63°	70°	67°	0.04	—		Heavy
" 19th	"	29.940	75.90	70°	29.721	76°	67°	72°	70°	0.67	—		Rain
" 20th	"	29.572	75.12	70°	29.458	80°	63°	78°	73°	0.60	—		Damp
" 21st	"	29.646	75.31	66°	29.544	97°	50°	70°	64°	0.04	Cirro-cumulus	S.W.	Fair
" 22nd	"	29.734	75.53	63°	29.641	88°	52°	65°	60°	0.13	"	N.E.	Fair
" 23rd	"	29.834	75.76	73°	29.864	78°	40°	70°	62°	0.00	—	S.W.	Fair
" 24th	"	29.836	75.78	68°	29.725	84°	50°	72°	64°	—			Overcast
" 25th	"	29.832	75.75	62°	29.762	82°	50°	52°	50°	0.49			Rain
" 26th	"	29.710	75.46	60°	29.626	73°	46°	48°	47°	0.41			Rain
" 27th	"	29.702	75.45	63°	29.609	74°	47°	70°	62°	0.32		W	Showers
" 28th	"	29.894	75.92	64°	29.697	78°	45°	71°	63°	0.30			Rain
" 29th	"	29.964	76.12	62°	29.819	82°	53°	78°	74°	—		S	Wet
" 30th	"	29.944	76.06	66°	29.842	86°	46°	88°	66	0.21		S	Showy
June 1st	"	29.892	75.97	69°	29.697	71°	64°	66°	64°	0.26		S	Overcast
" 2nd	"	29.890	75.96	68°	29.704	92°	56°	68°	67°	0.28			Showy
" 3rd	"	29.880	75.90	70°	29.704	91°	50°	80°	67°	—		SW	Fine
" 4th	"	29.632	75.37	69°	29.521	91°	58°	76°	67°	—		W	Fine
" 5th	"	29.500	74.93	70°	29.326	76°	57°	72°	65°	—		SW	Fair
" 6th	"	29.620	75.34	66	29.518	77°	50°	60°	58°	0.03		S	Fair
" 7th	"	29.872	75.89	66°	29.770	84°	46°	70°	66°	—		W	Fair
" 8th	"	29.740	75.54	70°	29.626	84°	60°	76°	70°	—			Overcast
" 9th	"	29.914	76.02	69°	29.738	90°	50°	80°	80°	0.02			Fair
" 10th	"	29.896	76.16	67°	29.838	100°	50°	76°	76°	0.02			Fair
" 11th	"	29.702	76.09	75°	29.813	100°	68°	91°	72°	0.02		W	Rain
" 12th	"	29.102	76.12	76°	29.010	93°	68°	88°	73°	0.13		W	Rain
" 13th	"	29.102	76.19	76°	29.819	92°	62°	86°	78°	—		W	Rain
" 14th	"	29.276	75.39	74°	29.750	93°	60°	82°	78°	—			Fair
" 15th	"	30.496	76.32	78°	29.900	100°	64°	89°	82°	—		SW	Fair
" 16th	"	29.916	76.00	76°	29.724	91°	67°	82°	73°	0.70		S	Fair
" 17th	"	29.908	75.93	77°	29.659	94°	65°	82°	79°	0.00		S	Fair
" 18th	"	29.772	75.62	69°	29.701	78°	60°	72°	68°	0.37			Fair
" 19th	"	29.896	75.98	77°	29.672	88°	68°	82°	76°	—	Rainbow	SW	Fair
" 20th	"	29.890	75.89	77°	29.755	88°	70°	78°	76°	—			Fair
" 21st	"	29.740	75.51	76°	29.658	89°	70°	75°	68°	—		N	Fair
" 22nd	"	30.306	76.49	71°	30.098	78°	64°	70°	65°	—	—	N	Fair
" 23rd	"	30.330	77.03	70°	30.218	76°	52°	72°	68°	—	—	NE	Fair
" 24th	"	30.284	76.92	70°	30.170	76°	53°	74°	67°	—		E	Fair
" 25th	"	30.046	76.32	72°	29.926	76°	60°	70°	72°	—		E	Hazy
" 26th	"	30.090	76.40	70°	29.972	90°	62°	80°	75	—		E	Fair
" 27th	"	30.090	76.42	78°	29.966	90°	62°	80°	75°	—		E	Fair
" 28th	"	30.012	76.24	73°	29.871	87°	71°	78°	77°	—		E	Fair
" 29th	"	30.032	76.28	76°	29.866	90°	70°	79°	75°	—		NE	Rain
" 30th	"	29.946	76.10	80°	29.932	90°	67°	76°	66°	0.24		N	"
July 1st	"	29.946	76.13	76°	29.688	72°	59°	68°	64°	0.35		N	"
" 2nd	"	29.884	75.98	76°	29.625	72°	58°	68°	63°	1.30		Calm	"
" 3rd	"	29.934	76.11	69°	29.884	75°	51°	70°	64°	1.60			"
" 4th	"	29.934	76.11	69°	29.884	75°	51°	70°	64°	0.04			Fair
" 5th	"	29.53	75.03	75°	30.002	80°	62°	75°	70°	—		NE	Rain
" 6th	"	30.124	76.59	79°	30.008	85°	62°	78°	72°	—		E	Fair
" 7th	"	30.024	76.25	76°	30.032	89°	62°	80°	71°	—			Fair
" 8th	"	30.024	76.26	77°	29.996	92°	65°	80°	71°	—		N	Fair
" 9th	"	29.894	75.99	77°	29.794	92°	65°	82°	72°	—		SW	Fair
" 10th	"	29.800	75.77	79°	29.692	90°	65°	82°	72°	0.11			Showy
" 11th	"	29.760	75.66	80°	29.716	93°	69°	78°	75°	—			
" 12th	"	29.784	75.74	73°	29.744	84°	64°	79°	71°	—		E	Fair
" 13th	"	29.784	75.74	73°	29.744	84°	64°	72°	71°	0.10		E	Fair
" 14th	"	29.850	75.91	77°	29.775	88°	65°	75°	72°	0.00			Overcast
" 15th	"	29.886	75.98	77°	29.790	90°	66°	80°	74°	—		NW	Fair
" 16th	"	29.900	75.98	76°	29.818	92°	68°	78°	75°	—		W	Fair
" 17th	"	29.814	75.72	76°	29.679	81°	62°	79°	75°	—		NW	Overcast
" 18th	"	29.946	76.16	75°	29.862	90°	66°	80°	76°	0.20		N	Fair
" 19th	"	29.945	76.10	78°	29.807	87°	67°	79°	74°	—		NW	Showy
" 20th	"	29.925	76.15	79°	29.844	87°	68°	79°	74°	—			Showy
" 21st	"	29.806	76.31	79°	29.711	85°	68°	80°	74°	—		E	Fair
" 22nd	"	29.770	76.15	76°	29.739	85°	62°	81°	75°	—		E	Fair
" 23rd	"	30.114	76.88	78°	29.881	85°	62°	81°	71°	—		NW	Fair
" 24th	"	29.730	75.82	71°	29.613	84°	70°	70°	77°	1.13		NE	Showy
" 25th	"	29.838	76.80	71°	29.727	78°	70°	70°	69°	—		N	Rain
" 26th	"	29.842	76.00	74°	29.744	78°	66°	69°	68°	—			
" 27th	"	29.732	75.53	74°	29.600	84°	70°	76°	74°	0.22		NE	Rain
" 28th	"	29.946	76.07	74°	29.820	86°	68°	82°	80°	0.00		E	
" 29th	"												
" 30th	"												
" 31st	"												



Meterexperiment, May 6th 1889

Experiment was made with a set of 9 meters of new pattern. Solution was of sp. gr. = 1.110, and of acidity of 8 drops of 10% N.S. having been boiled and filtered 3 weeks before starting the test. Lines were varnished on backside and edges, amalgamated while hot, on 4th of May, dried for 36 hs.

Distance between plates = 1/4".

Monday, 6th May 1889.

The plates were weighed, and put into their bottles, where they remained to May 9th.

No of plates	Weight on 6th May	Weight on 9th May	Loss	Gain	Meters connected in series	Resistance of meters	Place of meter	Remarks
4	118.162	117.593	.002	.034 .568	No 10	2.050 Ω	Hot box	
3	114.870	115.438		.020				
2	126.166	126.6885			No 7	4.107 Ω	Ice box	
1	116.236	115.765	.471	.051	No 9			
5	126.731	126.290	.441					
6	122.1715	122.6960		.034 .425	No 4	4.096 Ω	"	
7	116.844	117.375		.531	6			
8	120.921	120.248	.573	.002	No 12	2.053 Ω	Hot box	Smutted (slightly)
9	120.931	121.572		.641			"	"
10	127.742	126.906	.876	.035				
11	119.340	118.729	.611					
12	116.946	117.515		.002 .569	No 11	2.050 Ω	"	"
13	116.503	116.965		.462				
14	126.637	126.150	.487	.035			Ice box	Smutted (slightly)
15	120.280	119.405	.875					
16	126.136	126.902		.109 .766	No 1/3	4.158 Ω	"	
17	128.847	127.952	.895				Hot box	slightly smutted
18	127.279	128.119		.055 .840				

Plates No 2/3, 5/6, 13/14, 15/16 were contained in a Icebox, enveloped in ice, and kept at an average temperature of 40° F. Plates No. 1/4, 7/12, 9/11, 11/12, 17/18 were kept in a box warmed by a 16 c.p. lamp to an average temperature of 90° F. The current (strength) of 15 milliampères from 2 Bunsenells was passed through the meters for 50 hs, when the plates were taken out of their places, dried for only 1/2 h and weighed, the result of which is given above.

Out of the above given figures one can easily see that the loss prevail over the gain; this shows, that the solution was too acid, dissolving more time than precipitating.

Friday 10th May. Another test was made, in order to see the absolute effect of the solution being too acid:

12 plates were amalgamated as usually, and put aside in their bottles, containing solutions of different degrees of acidity (sp. gr. 1.110), remaining there for 68 hs.

No. plates	Weight on 10th May	Weight on 13th May	Loss	Acidity of solution
1	87.221	87.215	.006	Same as in
2	88.587	88.580	.007	foregoing test
3	85.723	85.702	.021	Added to smth.
4	79.190	78.155	.035	of the acid. 1 drop
5	83.700	83.640	.060	H_2SO_4
6	89.410	89.380	.030	added to the
7	85.910	85.875	.035	2 dr. H_2SO_4
8	79.721	79.710	.011	Added 3 dr.
9	88.463	88.401	.062	H_2SO_4
10	78.149	78.098	.051	+ 4 dr.
11	67.234	67.195	.039	H_2SO_4
12	78.543	78.500	.043	+ 5 dr. H_2SO_4.

Results of Motor Experiment on last page

No of plate	Weight before test	Weight after test	Gain or Loss	Bromphograins	Schumann by	Temp. °C. Mean	Res. of lamp @ temp.	Mean Loss + Gain				
1	116·365	117·763	−0·602	−0·025	2·050 w	32°	2·057	0·585				
2	114·870	115·868	+0·598									
3	116·236	115·765	−0·471	−0·051	4·107	4·5°	4·070	0·446				
4	126·736	126·682	+0·620									
5	126·731	126·290	−0·441	−0·016	4·096	4·5°	4·059	0·433				
6	121·515	121·940	+0·425									
7	116·864	117·375	+0·531	−0·014	2·053	32°	2·060	0·552				
8	120·851	120·278	−0·573									
9	120·731	121·572	+0·841	−0·035	∞	32°	∞	0·859				
10	127·782	126·906	−0·876									
11	114·360	114·749	−0·611	−0·042	2·050	32°	2·087	0·590				
12	116·826	117·415	+0·569									
13	116·503	116·965	+0·462	−0·025	4·158	4·5°	4·121	0·475				
14	126·637	126·150	−0·487									
15	120·280	119·405	−0·875	−0·109	∞	4·5°	∞	0·820				
16	126·136	126·902	+0·766	−0·059				0·870				
17	128·867	127·972	−0·895									
18	127·279	128·119	+0·840	−0·055	∞	32°	∞	0·868				

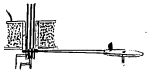
No of plate	Full Gain Rotor Weight	Mean Full Current W/t	W−10	Ratio W−10 / W	Res. = (W−10)/W	Mean Res.					
9, 10	0·859										
		0·866									
15, 16	0·870										
17, 18	0·868										
1, 2		0·281	0·281	0·480	0·988	1·041 @ 32°C					
7, 8		0·314	0·314	0·569	1·272						
11, 12		0·276	0·276	0·468	0·968						
2, 3		0·420	0·420	0·942	3·833	3·761 @ 4·5°C.					
5, 6		0·433	0·433	1·00	4·059						
13, 14		0·391	0·391	0·823	3·392						

Particulars of Phonograph Motor wound for Edison Light Co.

Field magnets wound with #30 0·012" wire Res: 170ω covered to 0·032"
Armature - - #35 0·005" " 30ω covered to 0·012"
about 1ω to the block.

At Factory motor run with 1 lamp + 60ω in ~~both~~ each circuit separately.
At laboratory run with 170ω in circuit of both + 40ω in cct: of armature.

The current in the armature cct was 0·40 amp: armature stopped
0·28 - - running.



May 15th

One large carbon was drilled out to hold within it a smaller concentrically. The two fitted into the a cylindrical shaft cut through the core of an electromagnet. This latter was fixed but the carbons could be thrown on their vertical axis by means of a separate wheel and pulley.

On passing the current through the electromagnet and so into the carbons bridged for contact, an arc was set up which rotated itself against the direction of the current in the magnet. This was accounted for by Ampère's law. If the electromagnet was left out of circuit then the arc burned at one spot and this spot did not shift on rotating the carbons nor was easy to cause its shifting by means of a separate electromagnet.

To find the coiling space required for 45w and also for 30w of No 35 B.W.G. copper wire having 2.422 feet per ohm.
= 108.9 feet for 45w and 72.4 feet.

Determination of the Constant of the Black Heavy coil Galvo.

17th May 89.

The two silver plates 11 X 2.7 cms used in a previous experiment were here employed immersed to a depth of 7.5 cms. in a neutral solution of $AgNO_3$.

The current from the 120 volt circuit was passed through about 70w so as to obtain approximately 2 ampères.

The deflections then obtained on the tangent scale were
0.411 clockwise and 0.411 counterclockwise.

At 9.40.00 the silver voltameter was brought in cct.
" 9.43.00 " " " " cut out.

The deflection during these 180 secs. was steady at 0.411 cct.

The weight of the cathode before was 17.690 gms after 18.112 gain 0.422
" " " " anode " " 17.808 " " 17.379 loss 0.429

Mean of gain and loss 426 mgms

4.26×10^{-4} gms / 1.80×10^{2} secs = 2.367×10^{-3} gms per sec.
$2.367 \times 10^{-3} \div 1.11815 \times 10^{-3}$ = 2.117 ampères.
$0.411 \div 2.117$ = 0.1942 Constant of Galvo.

Second trial

The same connections were used.

The deflections obtained were 0.410 very steady on each side.

At 10.44.00 the silver voltameter was brought in circuit
" 10.50.00 " " " " cut out of "

The weight of the cathode was 18.2205 and before 17.379 gain 0.8415
" " " anode " 17.2225 " " 18.112 loss 0.8895

a quantity of silver powder was noticed in washing the plates to fall from the anode. This was deposited silver that had evaporated reducing and thus was left as a fine powder without support.

Taking the gain as correct

8.415×10^{-4} gms $\div 3.60 \times 10^{2}$ secs = 2.3375×10^{-3} gms per sec.
$2.3375 \times 10^{-3} \div 1.11815 \times 10^{-3}$ = 2.090 ampères.
$0.410 \div 2.09$ = 0.1962 Constant of Galvo.

Taking mean we have 0.195 as the Constant.

With the ring tangent galvo in series with the Black ~~the~~ deflected steadily to 0.390 the deflection was 15°.15' clockwise and 15° 0' counterclockwise. Taking the mean as 15°.07' whose tangent = 0.27013 the tang. per amp: = 0.13507 or tan⁻¹ 7°.42'.

The two galvo: seems to exercise no appreciable influence on each other, as found

Meter Test.

The measurement of the res. of the bottles with 1.11 solution was repeated with neutral solution. The temperature of the bottles in the refrigerator was however not kept so low.

The test commenced at 13 o'clock on the 14th May, the current being 10 milliampères. In the refrigerator there were four bottles and in the warm box five. The results are shown in the following tables. The plates in the refrigerator were found to have slightly amitted.

No. of Plate	Weight 14th May	Weight of couple	Weight 17th May	Weight couple.	Gain:	Gain	Loss.	Acceptts	Mean temp	
1	116·962	231·919	117·256	231·896	−0·023	0·294				
2	114·957		114·640				0·317	0·317	10·3°	
3	125·835	240·145	125·500	240·148	+0·003		0·335			
4	114·310		114·648			0·338		0·336	"	
5	125·420	246·564	125·100	246·564	+0·010		0·320			
6	121·134		121·464			0·330		0·325	"	
7	116·434	235·694	115·861	235·696	+0·002		0·573			
8	119·260		119·835			0·575		0·574	"	
9	119·935	235·719	120·510	245·713	+0·006	0·575		0·578	34·5°	
10	125·784		125·203				0·581			
11	117·749	234·242	117·318	234·241	−0·001		0·431			
12	116·493		116·923			0·430		0·430	"	
13	116·074	241·470	115·655	241·480	+0·010		0·419			
14	125·396		125·825			0·429		0·424	"	
15	118·535	244·380	118·964	244·373	−0·007		0·436			
16	125·845		125·409			0·429		0·433	"	
17	126·884	253·702	127·463	253·710	+0·008	0·579				
18	126·818		126·247				0·571	0·575	"	
				Mean	−0·0002					

No. of plate	Res. of Shunt = 24·5°C	Res. of Sh. @ temp both sides	Fall Current weight	W − w	w	Res. bottle	Mean	Results by last trial	
1, 2	4·120	4·180		0·259	0·317	3·37ω			
3, 4	4·095	4·110		0·240	0·336	2·94ω	3·16ω @ 10·3°	3·76ω @ 4·5°	
5, 6	4·100	4·115		0·251	0·325	3·18			
7, 8	∞		0·576						
9, 10	∞								
11, 12	2·050	2·099		0·146	0·430	0·713			
13, 14	2·050	2·099		0·152	0·424	0·752	0·729	1·04ω	
15, 16	2·055	2·104		0·143	0·433	0·695	@ 34·5°	@ 32°	
17, 18	∞								

Temp: in refrigerator

4 hrs @ 58°F	=	232
7 - - 54°	=	378
2 - - 52	=	104
4 - - 50	=	200
2 - - 52	=	104
2 - - 48	=	96
7 - - 50	=	350
2 - - 50	=	100
15 - - 48	=	720
1 - - 48	=	48

Mean = 50·5°F
= 10·3°C.

Temp: in hot box.

2 hrs @ 88°F	=	176
2 - - 92	=	184
7 - - 94	=	658
2 - - 84	=	168
2 - - 90	=	180
2 - - 94	=	188
2 - - 88	=	176
9 - - 96	=	864
2 - - 86	=	172
2 - - 96	=	192
2 - - 98	=	196
2 - - 96	=	192
9 - - 98	=	882
2 - - 96	=	96

Mean = 94°F = 34·5°C.

Calculation of the res: of the meter resistance for Paris. Using the old bottle and solution (1.054). and assuming 1224 mgms of Zinc to the amp: hr.

With a shunt of 0.02 ω the res: in the bottle circuit has to be 24.46 ω when the current in the bottle will be $\frac{C \times 0.02}{24.46 + 0.02}$ or $\frac{1}{1224}$ C so that the desired relation is obtained.

The res: of the 1.054 bottle is taken as 2.36 ω @ 10°C
and 1.25 ω @ 25°C
a difference of 1.11 ω for 15°C.

$\therefore x(1.00388)^{15} - x = 1.11$

$\therefore$ $15 \times 0.0016818 = 0.02523 = \log^{-1} 1.0598$

$\frac{1.11}{0.0598} = 18.56$ ω @ 10°C. + 2.36 = 20.92 ω

18.56 ω @ 10° = 18.92 ω @ 15°C. + ~~2.36~~

18.92 ω + 1.77 = 20.69 + 3.77 = 24.46 ω required.

18.56 ω @ 10° = 19.67 @ 25° + 1.25 = 20.92 ω.

Take then 18.92 ω copper and 3.77 ω g.s.

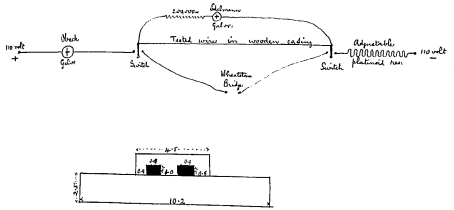
If the shunt resistance be 0.02 B.A. ohm, then the bottle will be 2.387 @ 10°
1.264 @ 25°
difference 1.123 for 15°

$\frac{1.123}{0.0598} = 18.78$ ω @ 10° + 2.387 = 21.167

18.78 @ 10° = 19.915 ω @ 15°

18.78 @ 10 = 19.9054 + 1.264 @ 25° = 21.167

Take then 19.15 ~~lg~~ ω of copper @ 15°
1.79 . . . bottle
3.52 . . . g.s.
21.46



Experiments on the Carrying power of Conductors:—

Took 24 ft samples of different sized covered wires to determine the rise in their temperature under certain conditions of environment and current. After several preliminary experiments the connections shewn on the opposite page were commenced with. Definite current strengths were passed through the wire for ten minutes at a time, the Edelmann Galvo observed with a telescope enabling an estimate to be formed of the permanent condition arrived. The switches were then thrown over and a bridge reading taken as quickly as possible afterwards.

The wooden lining was formed of a plank 20'4½" long 1" thick and 4" wide. On it was mounted a strip 1¾" wide ½" high and grooved with two parallel grooves ⅝" wide x ¼" high.

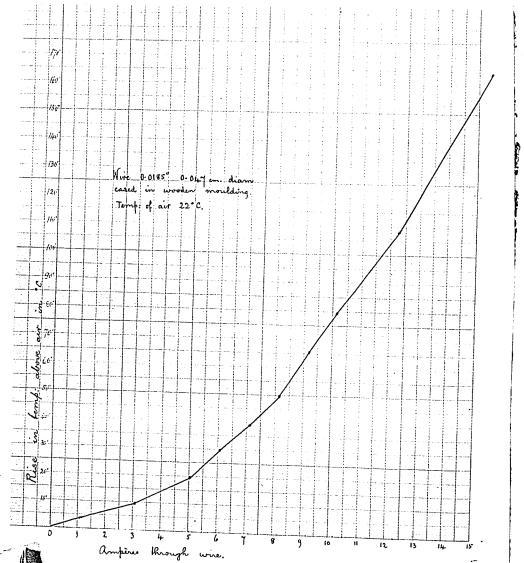
The first wire tried was marked grade 1 No 25 B.W.G.
The copper wire was 0·0185" diam = 0·01699 cms.
It was whipped with cotton to 0·024" = 0·06 "
and braided - 0·110" = 0·279 cms.
The tabular res: of this wire being 0·0259 ω per foot 20 ft = 0·516 ω.
Its length was 612 cms. and its res: @ 22°C was
by one measurement 0·5875 @ 25·5°C
0·588 @ 22°C. but

After the measurements were made, a test was taken to determine the coeff. for temp. @ follows:— The wire was coiled up and placed in a porcelain dish containing boiled linseed oil the dish was heated to 320°F and on cooling, the temperatures were observed and corresponding resistances obtained, while the oil was well stirred.

No of Obs.	Temp: Bath °F	Temp: Bath °C	Res: dish heads	Res: of wire	$(\frac{R}{r})^{\frac{1}{t}}$	log $\frac{R}{r}$	$\frac{1}{t}$ log $\frac{R}{r}$	1+x	x	R @ 0°C
1	72°F	22°	0·7420	0·5750 ω	0·588 ω					
2	310°	154·5	1·019	0·865	1·471	0·16761	0·001265	1·0026	0·26%	
3	300°	148·9	1·006	0·852	1·449	0·16107	0·001268	1·0026		
4	290°	143·3	0·998	0·844	1·435	0·15685	0·001293	1·0030	0·30%	
5	280°	137·8	0·982	0·830	1·412	0·14983	0·001294	1·0030		
6	270°	132	0·972	0·818	1·391	0·14333	0·001303	1·0030		
7	260°	126·7	0·963	0·809	1·376	0·13862	0·001324	1·0035	0·35%	
8	250°	121	0·950	0·796	1·354	0·13162	0·001330	1·0037	0·37%	0·5498
9	200°	93·3	0·8845	0·7305	1·242	0·09412	0·001320	1·0035	0·35%	
10	70°	21·1	0·739	0·585						

The sp: res: = $\frac{0·5498 \times 10^3 \times 0·001735}{612}$

$\frac{5·498 \times 1·735}{6·12} \times 10^3 = 1560$



On the carrying power of Conductors.

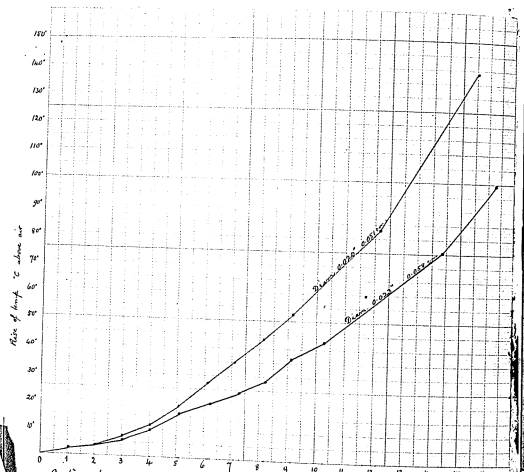
May 20th Monday.

No 1 Conductor

No. of Obs.	Time	Black Mean Deflec.	Current amperes	Temp. air.	Res. std.	Leads.	Res. wire.	$\frac{R}{r}$ (0·001393)	$\log \frac{R}{r}$	$\log \frac{R}{r}$ / $\log 1{\cdot}0034$	Rise of temp. °C.		T.B.
1	9.20	0	0	25·2°C	1·5660	0·9785	0·5875						26°
2	10.$\frac{0}{10}$ $\frac{0}{10}$	0·6	3·077		1·580	0·980	0·600 ?	1·021	0·009021	6·79	6·9	5·5	
3	10.$\frac{16}{32}$	1·00	5·128		1·623	0·980	0·643	1·094	0·039017	29·3	29	24·8	
4	10.$\frac{32}{32}$	1·212	6·214		1·673	"	0·693	1·180	0·071882	52·0	54	47·5	
5	10 $\frac{40}{40}$	0·695×2	7·126		1·669		0·689	1·173	0·069298	52·1	52	45·5	
6	11.$\frac{12}{40}$	0·710×2	7·282		1·670		0·690	1·17745	0·069185	52·5	52·5	46	
7	11.$\frac{27}{40}$	0·783×2	8·03		1·690	0·981	0·709	1·207	0·08171	61·4	61·5	54·5	
8	11 $\frac{34}{40}$	0·911×2	9·344		1·720 *		0·739	1·258	0·09964	74·9	75	68·0	
9	11.$\frac{48}{40}$	1·05×2	10·256		1·745		0·764	1·301	0·11428	85·9	86	79·5	
10	11.$\frac{53}{40}$	0·800×3	12·430		1·840		0·859	1·462	0·16495	124·0	124	124	
11	11.$\frac{53}{40}$	0·992×3	15·29		2·00	0·982	1·018	1·733	0·23880	179·5	179·5	193	23°

Some of these readings were very accurate partly from want of practice. The observation #8 marked with an asterisk was the first at which the two switches were turned simultaneously thus enabling the reading to be taken with less loss of time. The following set is much more reliable and is fairly accurate.

No. of Obs.	Time	Black Mean Deflec.	Current amperes	Temp. air	Res. std.	Leads.	Res. wire.	$\frac{R}{r}$ (0·001393)	$\log \frac{R}{r}$	$\log \frac{R}{r}$ / $\log 1{\cdot}0034$	Rise of temp. °C.		T.B.
1	13.27	0	0	26·7°	1·5695	0·978	0·5905						23°
2	13.$\frac{27}{40}$ $\frac{27}{40}$	0·2095	1·074		1·573		0·595	1·013	0·00561	3·34	3·3	3·4	
3	14.$\frac{12}{40}$	0·598	3·067		1·587		0·609	1·037	0·01578	9·38	9·4	9·7	
4	14.$\frac{24}{40}$	0·984	5·047		1·612		0·634	1·079	0·03302	19·64	19·6	22·9	
5	14.$\frac{40}{40}$	0·801×2	6·164		1·6375		0·6395	1·122	0·04997	29·73	29·7	32·0	
6	14.$\frac{55}{40}$ $\frac{55}{40}$	0·701×2	7·190	24·4	1·665	0·9815	0·6835	1·163	0·06558	39·0	39	42·8	
7	15.$\frac{14}{40}$	0·789×2	8·194		1·694		0·7125	1·213	0·08386	49·87	49·9	55·9	
8	15.$\frac{30}{40}$	0·901×2	9·240		1·7285		0·7570	1·288	0·10992	65·34	65·4	75·7	
9	15.$\frac{50}{40}$	0·995×2	10·205		1·7714		0·7935	1·349	0·13033	79·12	79·1	91·7	
10	15.$\frac{56}{40}$	0·799×3	12·295		1·8714		0·8925	1·519	0·18156	108	108	126·2	
11	16.$\frac{10}{40}$ $\frac{10}{40}$	1·004×3	15·450	22· 22·	2·0885	0·9815	1·1070 0·5875 Standard.	1·884	0·27548	163·6	163·6	232·	33°



Measurements of Heating of Current-carrying conductors.

(18)

May 21st Tuesday.

#2 Conductor tested marked #25 B&S gauge

Micrometer measurement gave diameter 0·020" = 0·0508 cms.
whipped to - 0·051
braided to - 0·100" = 0·254 -

Length 612 cms measured in moulding as before.

No. of Obs.	Time	Mean clock Deflection	Current amperes	Temp. air	Res. std.	Leads.	Res. wire	$\frac{R}{r}$ 0·003938	$\log\frac{R}{r}$	$\log\frac{R}{r}$ $\log 1{\cdot}00338$ 0·006816	Rise in temp. above air		Temp. Bridge
1	9.37	0	0	19.8°	0.8865	0.377	0.5095						19.8°
2	9.45	0.210	1.077		0.891		0.5114	1.009	0.00389	2.31	2.3	2.32	
3	9.52	0.396	2.031		0.894		0.517	1.015	0.00647	3.85	3.9	3.94	
4	10.15	0.598	3.067		0.9012		0.5212	1.029	0.01242	7.39	7.4	7.5	
5	10.35	0.794	4.072		0.909	0.376	0.533	1.0466	0.01953	11.62	11.6	11.9	
6	10.55	0.995	5.103		0.9235		0.5475	1.075	0.03141	18.68	18.7	19.4	
7	10.35	0.895×2	6.119		0.9420		0.5662	1.111	0.04571	27.18	27.2	28.6	
8	10.55	0.695×2	7.118		0.959		0.583	1.1454	0.05843	34.75	34.8	37.2	
9	11.25	0.797×2	8.174		0.9783		0.6023	1.182	0.07262	43.18	43.2	47.0	
10	11.40	0.895×2	9.20		1.001	0.3765	0.6245	1.226	0.08849	52.63	52.6	58.5	
11	11.55	1.097×2	10.33		1.0085	0.3	0.6220	1.2241	0.09377	55.77	55.8	62.2	
12	11.35	0.796×3	12.155		1.079		0.7025	1.379	0.13956	83.0	83.0	98.0	
13	11.55	1.011×3	15.55		1.250	0.3775	0.8725	1.712	0.23350	138.9	138.9	134.6	21.9°

#3 Conductor tested marked #23 B&S

Micrometer measurement gave diameter 0·023" = 0·0584
whipped to - 0·050" =
braided - - 0·120" = 0·3048

Length 612 cms measured in moulding as above.
The bridge used in this test was the Hartmann & Braun wire bridge, together with the 0·10 ω standard coil.

No. of Obs.	Time	Mean clock Deflection	Current Amperes	Temp. air	Bridge Reading	Amperes	Res.	Leads.	Res. wire	$\frac{R}{r}$	$\log\frac{R}{r}$ 0·003816	$\log\frac{R}{r}$ $\log 1{\cdot}00338$ 0·006816	Rise in temp. above air	Temp. Bridge
1	15.20	0	0	22.°C	0.396	0.604		0.0656						22.2
2	15.20	0	0		0.407	0.193	0.41892		0.3526					
3	15.30	0.210	1.077		0.408	0.192	0.4209		0.3553	1.008	0.00346	2.06	2.1	2.1
4	15.35	0.400	2.051		0.409	0.191	0.4236		0.3580	1.015	0.00647	3.85	3.9	3.9
5	16.45	0.591	3.031		0.410	0.190	0.4263		0.3607	1.023	0.01088	5.88	5.9	6.0
6	16.55	0.797	4.087		0.412	0.188	0.4320		0.3664	1.039	0.01662	9.88	9.9	10.1
7	16.55	1.002	5.137		0.415	0.185	0.4406		0.3750	1.064	0.02691	16.02	16.0	16.6
8	16.25	0.607×2	6.245		0.417	0.183	0.4465	0.3915/cm = 0.1556	0.3809	1.080	0.03312	19.97	19.9	20.9
9	16.35	0.713×2	7.312		0.419	0.181	0.4525		0.3869	1.097	0.04021	23.91	23.9	25.4
10	16.45	0.815×2	8.220		0.421	0.179	0.4588		0.3932	1.115	0.04737	28.11	28.1	30.0
11	17.55	0.893×2	9.158		0.425	0.175	0.4715		0.4059	1.151	0.06108	36.33	36.3	39.2
12	17.45	1.093×2	10.29		0.428	0.172	0.4815		0.4159	1.180	0.07188	42.75	42.7	46.9
13	17.35	0.796×3	11.73		0.436	0.164	0.5097		0.4441	1.260	0.10037	59.68	59.7	65.5
14	17.35	0.956×3	14.40		0.445	0.155	0.5452		0.4796	1.360	0.13351	79.84	79.8	93.5
15	17.25	0.997×4	16.35		0.454	0.146	0.5850		0.5192	1.470	0.16732	99.50	99.5	122.
16			0	22.°C.	0.400	0.600		0.0667						

May 22nd Wednesday.

Determination of constant of Siemens' Dynamometer thin wire coil.

Weighed plates of Silver Voltameter No 1. 17.221 } 35.4345
·2 18.2135
Pair 35.4345

17. 16. 30 Current on. through Voltameter.
Dynamometer reading 122°·20'. steady
Obach Ring - 0.920 × 2 →

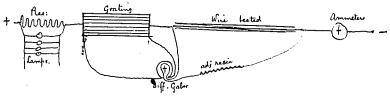
The strength of this current was too great for the voltameter which quickly assumed a spongy mass of bore deposited silver on the cathode. Probably therefore the current density should not exceed 0·1 amp. per sq. cm in order to obtain a good deposit.

17. 18. 20 Current off.
Time 110 seconds. Weight of plate no 1. 16.05 95 } 34.8315
- - - - 2 18.772
Pair 34.8315

Gain of no 2 0.5585 quite valuable
Loss - - 1 1.1615 gm.
Loss per sec. 0.01056 gm
Current 9.442 ampere.
Obach const. 0.1949 per amp.
$\sqrt{122.5}$ = 11.068
Dynamometer Const 0.8530 against tabular value 0.928
On the 16th May 88 the constant was calculated to be 0.857 $\sqrt{\tan}$
" " 12th Sept " - - - - - 0.862 $\sqrt{\tan}$

Took over comparison of deflections with Obach and the long Ammeter

Mean Obach reading 0·890 × 2 = 1·78 / 0.195 = 9·13 amp.
produced 0·5 deflection at mean dist. of 11·78 cm.
$11.78^2 = 138.77 + 36 = (174.77)^{\frac{1}{2}} \div 226.2 \times 1.89 = 19.204 \div 2 = 9.652.$
gave a reading consequently some 5% in excess.



Heating of Conductors.

May 23rd Thursday

Wire marked #21 B.W.G. Diam: by micrometer 0·0315" = 0·0800 cms
#4 Conductor. whipped to 0·045"
braided - 0·120" = 0·305 -

No. of Obs.	Time	Mean Mark Deflen.	Amperes	Mean Sum of Degrees Deflen. with Rdg.	Amperes	Mean Sum of Degrees Deflen. without Rdg.	Const.	Amplified Amperes	Bridge	0·1 ohm 90 Reading	Res. of Coil	Resist.	Res. of wire	$\frac{R}{r}$	$\log \frac{R}{r}$	$\log \frac{R}{r}$ POWER	Temp. cen. °C
1	9·45	0·000		74·5°					322	608		0·0645					
2	9·55	0·040	2·051	87·5°	2·34			2·051	1722	273	0·2636		0·1991	1·000			17·5°
3	9·55	0·805	4·128	25·3	4·29			4·128	728	272	0·2677		0·2072	1·021	0·00931	5·37	26·0
4	9·55	0·2999	6·143	26·3	5·81			6·14	732	268	0·2731		0·2084	1·028	0·02256	12·11	111·103
5	9·55	0·8202	8·221	93°	8·23			9·22	733	267	0·2745		0·2100	1·055	0·02327	13·93	117·121
6	9·55	0·9900	10·20	149·5°	10·15			10·20	739	261	0·2832		0·2187	1·099	0·04100	24·38	256·256
7	9·55	1·2002	12·31	214·5°	12·148	19°	2·82	12·31	746	254	0·2937		0·2282	1·146	0·05918	35·2	35·374
8	9·55	1·4832	14·44	308°	14·99	29·4	2·66	14·44	754	246	0·3066		0·2381	1·216	0·07493	50·5	50·583
9	10·05	0·0002	16·41	—		37·3	2·69	16·41	762	238	0·3202		0·2557	1·284	0·10857	64·25	64 72·8
10	10·25	0·9992	18·42			46·	2·72	18·42	771	229	0·3367		0·2722	1·367	0·13577	80·74	80 94
11	10·45	0·9972	20·25			54·2°	2·752	20·25	780	220	0·3546		0·2901	1·457	0·16346	97·2	96·117
12	10·55	1·1074	22·56			71·5°	2·666	22·56	792	208	0·3808		0·3163	1·589	0·20112	119·6	118 151
13									810	190	0·4263		0·3619	1·817	0·25935	154·2	152·209
									392	608		0·0645					19°

May 24th Friday

Brought into use a platinoid grating of forty wires 0·031" diam each 2·44 cms long approximately 2 ohms so that the resistance of the set is approx 0·05Ω. A preliminary test of this made the res: $\frac{2630}{2630 + 2672} = 0·0495$ @ 20·0°C. the two halves of this res: offered $\frac{2630}{6500 + 2670} = 0·0287\Omega$.
The Res: of the diff: galv: was as follows. Rt: hand coils 2671·5Ω mean @ 20·7°C.
Temp: galv: 20·2°C. Lft - - 2628·5 - - -

Wire tested diam: by micrometer 0·0446" = 0·112
#5 Conductor whipped to 0·070".
braided - 0·130" = 0·330

No. of Obs.	Time	Mean Mark Deflen.	Amperes	Mean Sum of Degrees Deflen. with Rdg.	Amperes	Mean Sum of Degrees Deflen. without Rdg.	Const.	Amplified Amperes	Res. in cat:	Ratio	Res. of wire	$\frac{R}{r}$ 0·001562	$\log \frac{R}{r}$	$\log \frac{R}{r}$ 0·00168	Rise in temp. above air	Temp. cen.
1	15·45	0·20	1·0						3270	306	0·1130					
2	15·55	0·1403	2·07			22°			3290	2·269	0·1134	1·003	0·00130	1·0	1·0	20·8°
3	15·55	0·807	4·14						3310	2·276	0·1188	1·007	0·00303	1·80	1·8	19
4	16·05	1·644	8·23			8°			3450	2·329	0·1165	1·031	0·01326	7·88	7·9	30
5	16·25	1·922	10·16			19·7			3555	2·369	0·1155	1·046	0·02078	12·36	12·4	37
6	16·35	2·404	12·33			20			3720	2·431	0·1286	1·076	0·03181	18·92	18·9	47·6
7	16·35	2·816	14·44			30			3890	2·495	0·1288	1·105	0·04336	25·79	25·8	57·2
8	16·55	3·220	16·51			38			4095	2·575	0·1289	1·140	0·05690	33·84	33·8	64·2
9	16·55	3·600	18·46			45·2			4260	2·635	0·1338	1·184	0·07335	43·61	43·6	67·6
10	17·05	4·000	20·51			69			4490	2·797	0·1399	1·238	0·09272	55·13	55·1	69·5
11	17·05	4·406	22·60			67·5			5015	2·924	0·1461	1·294	0·11193	66·56	66·6	76·0
12	17·35	4·805	24·64			87·5			5370	3·060	0·1530	1·354	0·13162	78·26	78·3	91·5
13	17·45	5·210	26·72			92°			5835	3·235	0·1618	1·432	0·15594	92·72	92·7	117°
14	17·55	5·644	28·95			105°			6480	3·481	0·1740	1·540	0·19722	117·5	117·5	20·8°
15																

Results of Storage Cell test.

Mean EMF for 11 hours	2·023 volts.
" P.D. at terminals	1·923 "
Int: res: discharging	0·005 ohms
" Current	14·9 ampères.
" Ampère hours	164 for 11 hrs.
" Watts out: energy	29·6
" Total Energy out	325·3 watt hours = 1,170,000 Joules
" No. of cells per H.P.	25·2 = 355 foot-lbs
" Weight of cells per HP	1160 lbs or 2 H.P. per ton (approx)
" Watts per lb. of cell out	0·64.

Test of a Storage Cell.

Received on May 22nd a storage cell manufactured by the Anglo-American Electric Light Manufg Co.

Its weight was 38·5 lbs. = 17·46 kilos when charged in all 46 lbs = 20·9 kilos

There were 4 + and 4 − plates, each {15·5 × 15·5 × 1·3 thick / 6⅛" × 6⅛" × ½"}

The area of each face {240 sq. cms / 37¼ sq. ins} so that the total active area = {3360 sq. cms / 522·5 sq. ins} on both sides

The separating distance between the plates = {0·7 cms / 1/4 in} or on each side {1680 sq. cms / 261 sq. ins}

The whole set of plates formed almost a perfect cube.

The plates were formed of lead strip 0·2 cm thick bent into regular loops ~~ecco~~ so that a large volume of material could be enclosed.

The solution was supplied with the cell. it is stated to consist of a mixture of pure H_2SO_4 and H_2O about 20% and sp.g. 1·18 g at normal temp. Its actual sp.g. was 1·195. The quantity of solution was 2500 c.c. The nominal capacity of the cell was 150 ampère-hours. Instructions were received from Mr Wirt to charge it to the extent of 300 ampère hours at rate of 20 for 15 hrs, then discharge it at rate of 15 till 1·75 volts was reached.

Commenced charging		10·15	24. 5. 89	Stopped 12 – 13
Stopped	-	1	25. 5. 89	
Recommenced	-	8·15	- -	
Stopped	-	9·30	- -	

Total time 15 hours. @ 20 ampères from 100 volt cct and lamp-tank.

At 9·0 ~~the~~ 25. 5. 89 the P.D. on the terminals while charging was 2·488 and when current of 20 ampères interrupted 2·260

Diff 0·128/20 = 0·0064 ω internal resis:

Density of charging current 0·012 amp per sq. cm.

The EMF after charging was 2·228 volts.

No. of Obs.	Time	EMF	P.D.	P.D. on 0·01	Current	Diff.	I.R.	Time of Disch.
1	10·20	2·136	2·054	0·081	16·0	0·052	0·0051	0
2	12·0	2·096	2·038	0·083	16·2	0·058	0·00358	1½
3	15·45	2·028	1·944	0·075	15·0	0·084	0·0056	5¼
4	16·30	2·024	1·936	0·075	15·0	0·088	0·0059	6
5	20·00	1·970	1·897	0·071	14·2	0·073	0·0051	9½
6	21·00	1·941	1·821	0·064	12·8	0·120	0·0094	10½
7	22·00	1·810	0·600	0·041	8·2	1·210	0·149	11½
	Ampère hours by acc.		1½ @ 16·2	= 24·3				
			4½ @ 15·2	= 68·4				
			3½ @ 14·5	= 50·8				
			1 @ 13·5	= 13·5				
			1 @ 10.	= 10				
			11½	167·0				

The cell was discharged through Standard Edison meter #10998 and the Ampère which coincidente distinctly, also the Standard 0·01 ω.

The weight of the plates at 9·0 o'clock was no 1 113·346 no 2 121·9234

" " " " " " 22·30 " " " 113·5488 " " 121·7145

+ 0·2035 − 0·2095

Mean 0·206

0·206 in the bottle cct is equivalent to 206 gms in shunt cct

$\frac{206}{1·224}$ = 168·3 ampère-hours.

2629 = @ 15·5 & 18 = 2·5° C @ 0·388% = 0·97% = 26 excess
= 2655 ω.

Carrying Capacity of Conductors.

Sunday 26th May

Compensated the error of magnetic influence + res: in the Edelmann differential galv: Residual differential error quite negligible and compound coils of equal resistance to 1ω.

27th May Monday

Measured more accurately the res: of the platinoid grid.

Res: of galv. 5263 or 2631·5 in each coil T.B. 15·8 = 3° from std temp.
= ·03 % = 2·4 — or 2629 ω

Res: in cct: with 0·1ω @ 15·5° C 2752 ω = about 2750.

Res: of std: @ 17·2° 0·10022 ω @ 15·5 = 1·7° × ·02 % = ·034% = 0·10025 ω.

" " grid = $\frac{2625}{2750 + 2629}$ × 0·10025 = 0·04899 ω @ 15° C.

Compared the two halves. found balance at 10 amperes with 7ω added to the one both side

or x : 0·04899 − x :: 2636 : 2629 whence x = 0·02453 ω } @ 15° C.
2 both sides = 0·02446 ω

Wire tested as follows:—

Diameter 0·051" = 0·1295 cm

#6 whipped to 0·075"
brazed to 0·120 = 0·305 cm.

No of obs	Time	Mean Steel Deflec.	Amperes	Specific Dynes Shunt cct	Resistance	Temp 84 Res added to wire cct.	Ratio of wire	Ratio $\frac{R}{r}$	log $\frac{R}{r}$	log $\frac{R}{r}$ / 0·006818	Rise in temp. above air °C	Temp. air
1	13·40	0·222			1588		0·0776					18·2°
2	13 $\frac{55}{60}$	0·899	2·046	"	1565		0·0779	1·0024	0·00173	1·03	1	
3	13 $\frac{58}{60}$	1·004	5·169		1605		0·0786	1·013	0·0561	3·34	3·3	
4	14 $\frac{55}{60}$	1·610	8·256	10°	1670		0·07933	1·029	0·02242	7·38	7·4	
5	14 $\frac{55}{60}$	2·038	10·45	16	1730		0·07996	1·043	0·01828	10·88	10·9	
6	14 $\frac{55}{60}$	2·398	12·30	22	1805		0·08232	1·061	0·02572	15·29	15·3	
7	14 $\frac{55}{60}$	2·804	14·38		1920		0·08444	1·088	0·03663	21·78	21·8	
8	14 $\frac{55}{60}$	3·221	16·46	36	2·743	2025	0·08640	1·113	0·04650	27.65	27·7	
9	15 $\frac{5}{60}$	4·020	20·62	51	2·889	2295	0·09139	1·178	0·07115	42·31	42·3	
10	15 $\frac{55}{60}$	4·384	22·49	59·5	2·918	2465	0·09352	1·218	0·08565	50·93	50·9	
11	15 $\frac{55}{60}$	4·808	24·66	82	2·722	2680	0·09850	1·269	0·10346	61·51	61·5	
12	15 $\frac{55}{60}$	5·240	26·87	99·5	2·695	2987	0·10868	1·341	0·12743	75·79	75·8	
13	15 $\frac{55}{60}$	5·621	28·87	115	2·698	3260	0·1192	1·407	0·14829	88·18	88·2	
14	15 $\frac{55}{60}$	6·012	30·82	125·5	2·724	3522	0·1260	1·469	0·16702	99·32	99·3	
15	16 $\frac{25}{60}$	6·396	32·80	143	2·733	3800	0·1391	1·535	0·18611	110·66	110·7	
16	16 $\frac{55}{60}$	6·796	34·86	163·5	2·724	4215	0·1268	1·631	0·21325	126·83	126·8	20·5°

Specific res: as follows:—

Balance @ 15° air $\frac{4129}{2629}$ × 0·029 ω. = 0·07712 ω.

log $r_{(0)}$ = log ·07712 − 15 log 1·00388
= −2·88717 − 0·02523 = 3·86194.

r = 0·07277 ω.

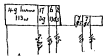
sp. res. = 0·07277 × 0·01317 × 10^3/612 = $\frac{7.277 \times 1.317}{6.12} \times 10^3$ = 1567 = 101·1%

Particulars of Phonograph Motor wound for Electric Light ccts.

May 27th + 28th

Tested two machines from the phonograph factory

The field cct: measures about 170 ω wound with no. 30 copper wire d.c.
" armature " " " 30 ω " " " 35 " " "
" res: in cct: with the machine was experimentally determined to be 65'.4" of no 30 platinoid B.W.G 0.012" offering 1.82 ω per foot.
Wound on a spool of 16" to the turn and 8 turns to the inch gave



4 avg turns of 113 ω res. to the field magnets and an additional

17 turns or	82'.6"	to	100 volts armature cct	=	39 ω extra or	152 ω in all
6 " or	90'.	"	105 "	"	" = 13.5 ω	" " 165.5 " "
6 " "	97'.6"	"	110 "	"	" = 13.5 ω	" " 179 " "
6 " "	105'.0"	"	115 "	"	" = 13.5 ω	" " 192.5 " "
Total = 84	" "		105.0			192.5 " "

In work this wire becomes appreciably warm.

The current in the armature cct: was 0.36 amp: stipped volts 12.6
" " " " field " " 0.32 " running " 19.5
" " " " field " " 0.25 "

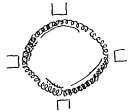
so that the total current running is 0.57 amp. × 110 volts = 62 Watts.

19.5 − 10.7 = 8.8 volts the counter e.m.f of the machine at about 170 revs: per min:

The res: necessary to control the spark in governing was about 60 ω, less than this made the governor useless, but even at 60 ω there was too much sparking.

A small condenser about 0.03 μf was apparently more efficacious.

On the conversion of the multipolar dynamo into an alternating-current machine



By reversing the windings as many times in the circle as there are poles to the machine, the maximum e.m.f. would be the present constant e.m.f. in each sector. and the mean alty. emf would be $\frac{2}{\pi}$ time this or the present emf say 140 volt × 0.6366 = 89 × 8 = 712

There would be 8 alternations or 4 complete periods per rev:
$= \frac{6400}{60} = 107$ alternations 53.5 complete periods per sec: @ 800 revs:

Carrying Capacity of Conductors.

87 Wire tested Kenite No 14 B.W.G. 0·064" = 0·163 cms.
covered to 0·210" = 0·533 "

Potentiometer in cct with the wire hooks. Half of grid = 0·02445 v. Res. Galv 2660 ω. 17°C.

No. of Obs.	Time	Clock	Siemens	Potentiometer Rdg	Clock Const.	Siemens Const.	Mean Potentiometer Rdg	Amperes	Res. in cct with wire	Total res. in wire cct	r_{mg} δ	Max. of wire
1	9·10	0·2		0·0105					250	2890	1·095	0·05362
2	9·$\frac{10}{20}$	0·8	1·5	0·0495	0·288	$\frac{2·295}{2·583}$	0·0269	4·00	260	2900	1·099	0·05874
3	·$\frac{55}{20}$	1·6 (a)	8°	0·103	0·1903	$\frac{2·297}{2·486}$	0·1029	9·40	287	2927	1·109	0·05717
4	$\frac{55}{20}$	2·0 (a)	12·5°	0·130	0·1885	$\frac{2·337}{2·526}$	0·1301	10·62	307	2947	1·116	0·05705
5	·$\frac{55}{20}$	2·4 (a)	17°	0·1508	0·1950	$\frac{2·35}{2·545}$	0·1561	12·74	330	2977	1·128	0·05719
6	·$\frac{55}{20}$	3·01 (a)	33°	0·1978	0·1864	$\frac{2·41}{2·596}$	0·2000	16·33	380	3020	1·1144	0·05734
7	·$\frac{55}{20}$	3·60 (b)	38°	0·2328	0·1895	$\frac{2·405}{2·595}$	0·2351	19·19	?			
8	·$\frac{55}{20}$	4·40 (b)	54°	0·2816	0·1914	$\frac{2·43}{2·627}$	0·2805	22·90	535	3175	1·203	0·06273
9	·$\frac{55}{20}$	4·80 (b)	76·5°	0·3204	0·1836	$\frac{2·454}{2·637}$	0·3208	26·19	565	3205	1·2114	0·06451
10	10·$\frac{55}{20}$	4·96 (a)	92°	0·3304	0·1864	$\frac{2·49}{2·676}$?	0·3311	27·03	625	3365	1·275	0·06838
11	11·$\frac{55}{20}$	5·92 (a)	103·5°	0·3964	0·1830	$\frac{2·515}{2·698}$	0·3973	32·43	822	3462	1·311	0·07020
12	11·$\frac{55}{20}$	6·88 (a)	158°	0·4705	0·1793	$\frac{2·55}{2·729}$	0·4746	38·75	1125	3765	1·4226	0·07648
13	11·$\frac{55}{20}$	7·92 (a)	212°	0·5473	0·1773	$\frac{2·587}{2·764}$	0·5439	44·40	1460	4100	1·553	0·07330
14	11·$\frac{55}{20}$	8·92 (a)	269°	0·6159	0·1774	$\frac{2·627}{2·804}$	0·6142	50·14	1900	4540	1·720	0·09224
						3·084						

No. of Obs.	$\frac{R}{r}$	log $\frac{R}{r}$	log $\frac{R}{r}$ / 0·006810	No. of log. of Temp.	Temp: air	No. of °C. wire, cell for change in temp	log r_{mg} − log 1·0485	r_{20}	$r \times \frac{0·00393}{612}$	$\frac{\delta}{r}$ per °C	$\frac{\delta}{r}$ Cmds	
1	1				17°		2·70092	0·05032	1655			
2	1·002	0·00173	1·029	1		1			$\frac{50000 \times 0·0000}{6·26·10^{-4}}$	2 1·095	17·40	
3	1·013	0·00561	3·336	3·3		3·3						
4	1·0195	0·00839	4·989	5		5						
5	1·030	0·01284	7·64	7·6		7						
6	1·0445	0·01912	11·37	11·4		10						
7	1·099											
8	1·099	0·04100	24·38	24·4		24						
9	1·109	0·04493	26·72	26·7		25						
10	1·165	0·06633	39·45	39·5		37·5						
11	1·197	0·07807	46·44	46·4		44·4						
12	1·302	0·11461	68·14	68·1		66						
13	1·419	0·15198	90·38	90·4		88						
14	1·571	0·19616	116·7	116·7		113·2						
					20·5°							

On the ratio between the wave lengths recognisable by the bolometer and those ~~producable~~ capable of being produced electrically.

The greatest wave-length yet appreciated by Langley's bolometer is stated by him as 30 μ = 300,000 tenth metre = $3·0 \times 10^{-5}$ cms.

The period of the shortest wave length hitherto electrically excited is given by Hertz Lodge + Rowland as the $1·0 \times 10^{-9}$ sec.

The corresponding wave-length = $\frac{3·0 \times 10^{10}}{1·0 \times 10^{9}}$ = 3×10^{1}

The ratio between these is thus 10^{6}

For mean visible rays it is $5·0 \times 10^{-5}$ and 3×10^{1} = $0·6 \times 10^{7}$ = $6·0 \times 10^{6}$

Carrying Power of Conductors.

May 20th Thursday

For Wire tested #16 B.W.G. Magnet wire 618 cms long) diam 0.064" = 0.162 cms
corrected to 0.055" = 0.216

Resr. of rock init. galv. 2.657

Ref. No.	Time	Clock	Bordat	Galvanometer Reading: Swinging down	Galvanometer Reading: Equilibrium	Potentiometer Rdg.	Amperes	Mean Potentiometer Reading	Amperes	Resr. in ckt. with wire	Total Resr. on wire side
1	11.30	0.2.			2.87				1	70	2727
2	35/20	0792	0.195	2°	2.62 / 3.4884	0.0297	1.058	0.0296	4.05	102	2759
3	40/20	1.0598 (1)	0.193	10°	2.62 / 3.6916	0.1016	8.294	0.1029	8.6[illegible]	140	2797
4	50/20	2.38 (1)	0.178	24°	2.72 / 3.673	0.1634	13.34	0.1638	13.37	217	2874
5	55/20	3.28 (1)	0.183	41°	2.81 / 3.635	0.2198	17.94	0.2284	18.65	325	2982
6	10/20	4.06 (1)	0.177	59.75°	2.91 / 3.866	0.2814	22.97	0.2755	22.49	465	3122
7	35/20	4.74 (1)	0.180	79°	2.94 / 3.885	0.3218	26.27	0.3216	26.26	635	3292
8	50/20	5.56 (1)	0.178	109.5°	2.99 / 3.944	0.3835	31.31	0.3839	31.34	850	3507
9	40/20	6.45 (1)	0.175	150°	3.01 / 3.924	0.4522	36.92	0.4545	37.10	1212	3869
10	50/10 min	7.24 (1)	0.175	178°	3.10 / 3.230 ?	0.5067	41.36	0.5079	41.47	1510	4167
11	55/20	7.94 (1)	0.172	219°	3.13 / 3.203	0.5658	46.20	0.5666	46.26	1915	4572
12	55/20	8.78 (1)	0.171	276.7°	3.19 / 3.240	0.6276	51.24	0.6313	51.54	2430	5087
					Mean 3.08			0.6310	51.51	2467	5117

Ref. No.	Res. of wire	$\frac{R}{r}$	log $\frac{R}{r}$	$\frac{\log R/r}{0.0016818}$	W. of Rise	Temp. air	Rise ckt. for change of air temp.	log r_0 −18 log 1.00138	r_0	$\frac{I \times 0.02096}{618}$	% Bord.
1	0.05030					18°C.		[illegible]	0.046944	15844	100%
2	0.05069	1.0120	0.00518	3.08	3.1		− 3.1	2.67130			
3	0.05158	1.025	0.01072	6.37	6.4		6.4				
4	0.0530	1.0537	0.02268	13.49	13.5		13.10				
5	0.0550	1.0934	0.03878	23.06	23.1		22.5				
6	0.05759	1.1448	0.05873	34.92	34.9		34.4				
7	0.06072	1.2072	0.08178	48.63	48.6		48.0				
8	0.06468	1.2860	0.10934	64.94	64.9		64.3				
9	0.07136	1.4190	0.15198	90.37	90.4		89.7				
10	0.07685	1.5280	0.18412	109.5	109.5		108.6				
11	0.08432	1.6760	0.22427	133.4	133.4		132.6				
12	0.09302	1.8650	0.27068	160.9	161.		160.				
13	0.09436	1.876	0.27323	161.3	161.3	19.5°	160.3				

A test was made of the comparison of two phonograph motor armatures one made up of soft iron plates in the usual way, the other of cast iron entirely.

When both armatures in series with 100 volt ckt. and res. the wrought iron ran 50% faster than the other, the machines and governors being disconnected.

When machine at work taking chip with battery

Current on wrought iron arm: machine 3.5 amp 1.6 volt = 5.6 Watts

" " cast " " 3.8 " 1.55 " = 5.9 "

This was owing to the shrinkage of the cast iron distinctly more chamm with it than with the wrought iron. Probably 50% more, and this it was estimated amply accounted for the deficiency here shown

Carrying Power of Conductors.

Wire tested 618 cms of # 14 B.W.G. black magnet wire diam = 0.2108
Day 31st Friday. Resistance 2.671 Rec. Galv. 2.658 Amp. 2660 19.4° density covered 6 0.102 " = 0.259
length 618 cms. between connection.

No. of Obs.	Time	Shock Rdg.	Const.	Sensitive Dipm. Rdg.	Const.	Long Range Ammeter	Potentiometer Rdg.	Amperes	Mean Potentiometer reading	Amperes	Res. in cats with grading
1	9.40	0.2					0.0102	0.829			1600
2	10/50	0.800	0.1995	5.5°	1.7		0.0293	4.009	0.0290	3.904	1580
3	20/75-10	1.606 (1)	0.1976	7.25°	3.58'		0.1000	8.13	0.1019	8.284	1540
4	20/70	2.450 (2)	0.191	20.5°	3.58 ?		0.1580	12.85	0.1577	12.82	1485
5	18/50	3.190 (3)	0.188	34.5°	2.89		0.2082	16.93	0.2091	17.00	1412
6	20/70	3.960 (4)	0.187	48°	3.06		0.2611	21.23	0.2659	21.62	1317
7	30/70	—		78°	2.88	3.8	0.3127	25.43	0.3124	25.40	1200
8	20/70	—		109.5°	3.15	5.1	0.3904	31.74	0.40048	32.91	1000
9	14.55/17.50	—		144.5°	2.97	5.8	0.4429	36.01	0.44449	36.17	880
10	20/70	—		174°	3.01	6.5	0.4986	40.55	0.4891	39.77	745
11	15/30	—		223°	3.08	7.4	0.5673	46.13	0.5634	45.81	537
12	30/50	—		276.7°	3.40	8.1	0.6308	51.30	0.6360	51.71	310
13	30/50	—		338°	3.09	7.8	0.6986	56.80	0.6980	56.75	120
					Mn 3.07						

No. of Obs.	Total res. on grading side	res. of wire	$\frac{R}{r}$	Log $\frac{R}{r}$	Log $\frac{R}{r}$ 0.004618	Room temp. °C.	Temp. rise	Corrected Room temp.	Log r_{19} − 10 by Lorenz	$\frac{t \text{ r.c.}}{00}$ 0.0332/0.004618 / 4.75	$\frac{I}{\text{Cond.}}$
							17.8°C		r.		
1	4260	0.03060	1.00429						$\bar{2}.455245$	1623	
2	4240 (1)	0.03044	1.0047	0.00204	1.21	1.2	.1	1.1			
3	4200 (2)	0.03102	1.0189	0.00600	3.57	3.6	.2	3.4			
4	4165 (3)	0.03144	1.0292	0.01157	6.88	6.9	.3	6.6			
5	4072 (4)	0.03240	1.0557	0.01941	11.54	11.5	.4	11.1			
6	3987 (5)	0.03277	1.0710	0.02979	17.71	17.7	.5	17.2			
7	3860 (6)	0.03376	1.103	0.04258	25.32	25.3	.6	24.7			
8	3660 (7)	0.03560	1.163	0.06558	39.0	39.0	.7	38.3			
9	3540 (8)	0.03681	1.203	0.08027	47.73	47.7	.8	46.9	0.028524		
10	3405 (9)	0.03827	1.251	0.09726	57.84	57.8	.9	56.9			
11	3197 (10)	0.04076	1.332	0.12450	74.02	74	1.0	73			
12	2970 (11)	0.04388	1.434	0.15655	93.09	93.1	1.1	92.			
13	2780 (12)	0.04688	1.532	0.18526	110.2	110.2	1.2	109			
							19.0°				

Carrying Power of Conductors.

#10

May 31st Friday) Wire tested of 116 B.W.G. double covered soft copper diamr. 0.053" = 0.2110cm
Temp. Galv. 20°C Res. 2670ω each end. covered to 0.100 = 0.254cm

No. of Obs.	Time	Object Rly.	Comut	Specimen Deflcn.	Comut	L.R. Amp.	Potnto Rly.	Amperes	Mean Potnto Rly.	Amperes	Res: on end with grading
1	15.10	-					0.07224	1.058			1700
2	$\frac{10}{20}$	0.800	0.2014	1°			0.04482	3.919	0.04287	3.960	1670
3	$\frac{20}{20}$	1.660 (1)	0.1943	8°.25	2.99		0.1051	8.5244	0.1038	8.438	1662
4	$\frac{30}{20}$	2.406 (2)	0.1922	22.3°	2.65		0.15240	12.52	0.1539	12.51	1574
5	$\frac{40}{20}$	3.240 (3)	0.1901	38.2°	2.76		0.2096	17.014	0.21024	17.11	1493
6	$\frac{50}{20}$	-		46°	3.13		0.2666	21.67	0.2669	21.70	1385
7	$\frac{50}{10}$	-		75°	3.05		0.3251	26.43	0.3157	25.67	1262
8	$\frac{50}{5}$	-		110°	2.99		0.3864	31.42	0.3875	31.51	1102
9	$\frac{50}{10}$	-		{149° / 152°}	3.06 / 3.014		{0.4590 / 0.46685}	37.32 / 37.55	0.46621	37.90	875
10	$\frac{40}{20}$	-		177°	3.00	5.8	0.4902	39.86	0.4943	40.19	752
11	$\frac{30}{20}$	-		218°	3.03	6.2	0.5490	44.63	0.5493	44.66	577
12	$\frac{20}{20}$	-		273°	3.01	6.9	0.6112	49.69	0.6132	49.86	380
13	$\frac{10}{20}$	-		343°	3.014	7.7	0.6915	56.22	0.7035	57.20	120
					Mean 3.03						

No. of Obs.	Total Res: on grading side	Resistd. Wire	$\frac{R}{r}$	$\log \frac{R}{r}$	$\log \frac{R}{r}$ / 0.0056818	Temp. air	Corrected Rise of temp.	log r −18 log 1.00338	sp. r. 0°C. 0.229	Coundi	Amp.
			0.093866								
1	4370	0.02995	1.008	0.00209		19.4°0		$\bar{2}.146613$	0.02993x		
2	4340	0.03014	1.005	0.00217	1.20 1.3	.1	1.1	.log 0.02993	0.03146 616	1097	3.46
3	4302	0.03041	1.014	0.00604	3.59 3.6	.2	3.4				6.44
4	4244	0.03082	1.027	0.01157	6.88 7.0	.3	6.6		1585		12.5
5	4162	0.03143	1.048	0.02036	12.1 12.4	.4	11.7				17.1
6	4055	0.03226	1.076	0.03181	18.92 19.7	.5	18.4				21.7
7	3932	0.03327	1.109	0.04493	26.72 27.2	.6	26.1				25.7
8	3772	0.03461	1.156	0.06296	37.44 38.5	.7	36.8				31.5
9	3555	0.03685	1.229	0.08955	53.26 54.4	.8	52.5				37.9
10	3424	0.03820	1.273	0.10483	62.34 63.4	.9	61.4				40.2
11	3247	0.04028	1.343	0.12808	76.16 77.7	1.0	75.2				44.7
12	3050	0.04290	1.430	0.15534	92.38 93.1	1.1	91.3				49.3
13	2790	0.04688	1.563	0.19396	115.34	1.2	114.0				57.2
						20.8°C.					

Meter Test. Measurement of the Rest of the new bottles.

This test commenced on the 27th May. 8 bottles were made up of the forms shewn on the opposite page. The density of solution was 1.110 and the solution was neutral. Five of these bottles were put in a warm box and three in the refrigerator. The temperature record in °F. was as follows:—

No. of Obs.	Date & Time	Period hours	Temp. °F.	Hot Box Mean	Temp. Hours	Refrigerator Temp. °F.	Refrigerator Mean	Temp. Hours	No. of Obs.	Date & Time	Period hours	Temp. °F.	Hot Box Mean	Temp. Hours	Refrigerator Temp. °F.	Refrigerator Mean	Temp. Hours
1	23.5 9.0		88	89	178	43	42		1	23.5 9.0		85	89	178	44	42	178
2	12.0	2	90	90	18.0	41	41		2	12.0	3	85	90	18.0	43	41	18.0
3	4.0	2	90	90	180	41	41	90	3	4.0	6	102	96	180	42	42	90
4	3.0	1	90	90	180	42	42	42	4	3.0	2	96	96	180	42	42	42
5	2.0	2	90	90	180	42	42	42	5	2.0	3	96	96	288	42	42	126
6	7.0	5	90	90	450	41	41	41	6	7.0	5	-	-	-	41	41	41
7	12.0	5	90	90	450	41	41	41	7	12.0	5	102	102	510	41	41	205
8	8.0	1	90	90	90	41	41	41	8	8.0	2	102	102	204	41	41	82
9	10.0	2	90	90	180	41	41	82	9	10.0	2	102	102	204	41	41	82
10	14.0	4	90	90	360	41	41	164	10	14.0	4	96	96	384	41	41	164
11	19.0	5	90	90	450	42	42	210	11	19.0	5	96	96	480	42	42	210
12	22.0	3	90	90	270	42	42	126	12	22.0	3	96	96	288	42	42	126
13	23.5	1.5	90	90	135	42	42	63	13	23.5	1.5	96	96	144	42	42	63
14	24.5	1	90	90	90	42	42	42	14	24.5	1	96	96	96	42	42	42
15	1.5	1	90	90	90	41	41	41	15	1.5	1	96	96	96	41	41	41
16	2.5	1	90	90	90	41	41	41	16	2.5	1	96	96	96	41	41	41
17	8.0	5.5	90	90	495	41	41	225	17	8.0	5.5	96	96	528	41	41	225
18	12.0	4	90	90	360	42	42	168	18	12.0	4	96	96	384	42	42	168
19	16.0	4	90	90	360	42	42	168	19	16.0	4	96	96	384	42	42	168
20	19.0	3	90	90	270	42	42	126	20	19.0	3	96	96	288	42	42	126
21	20.0	1	90	90	90	42	42	42	21	20.0	1	96	96	96	42	42	42
22	21.0	1	90	90	90	42	42	42	22	21.0	1	96	96	96	42	42	42
23	22.5	1.5	90	90	135	42	42	63	23	22.5	1.5	96	96	144	42	42	63
24	23.5	1	90	90	90	42	42	42	24	23.5	1	96	96	96	42	42	42
25	1.5	2	90	90	180	42	42	84	25	1.5	2	96	96	192	42	42	84
26	3.5	2	90	90	180	42	42	84	26	3.5	2	96	96	192	42	42	84
27	5.5	2	90	90	180	42	42	84	27	5.5	2	96	96	192	42	42	84
28	7.5	2	90	90	180	42	42	84	28	7.5	2	96	96	192	42	42	84
29	9.5	2	90	90	180	42	42	84	29	9.5	2	96	96	192	42	42	84
30	11.5	2	90	90	180	42	42	84	30	11.5	2	96	96	192	42	42	84
31	13.5	2	90	90	180	42	42	84	31	13.5	2	96	96	192	42	42	84
32	15.5	2	90	90	180	42	42	84	32	15.5	2	96	96	192	42	42	84
33	17.5	2	90	90	180	42	42	84	33	17.5	2	96	96	192	42	42	84
34	19.5	2	90	90	180	42	42	84	34	19.5	2	96	96	192	42	42	84
35	21.5	2	90	90	180	42	42	84	35	21.5	2	96	96	192	42	42	84
36	23.5	2	90	90	180	42	42	84	36	23.5	2	96	96	192	42	42	84
37	1.5	2	90	90	180	42	42	84	37	1.5	2	96	96	192	42	42	84
38	3.5	2	90	90	180	42	42	84	38	3.5	2	96	96	192	42	42	84
39	5.5	2	90	90	180	42	42	84	39	5.5	2	96	96	192	42	42	84
40	7.5	2	90	90	180	42	42	84	40	7.5	2	96	96	192	42	42	84
41	9.5	2	90	90	180	42	42	84	41	9.5	2	96	96	192	42	42	84
42	11.5	2	90	90	180	42	42	84	42	11.5	2	96	96	192	42	42	84
43	13.5	2	90	90	180	42	42	84	43	13.5	2	96	96	192	42	42	84
44	15.5	2	90	90	180	42	42	84	44	15.5	2	96	96	192	42	42	84
45	17.5	2	90	90	180	42	42	84	45	17.5	2	96	96	192	42	42	84
46	19.5	2	90	90	180	42	42	84	46	19.5	2	96	96	192	42	42	84
47	21.5	2	90	90	180	42	42	84	47	21.5	2	96	96	192	42	42	84
48	23.5	2	90	90	180	42	42	84	48	23.5	2	96	96	192	42	42	84
49	24.5	1	90	90	90	42	42	42	49	24.5	1	96	96	96	42	42	42
50	1.0	2	90	90	180	42	42	84	50	1.0	2	96	96	192	42	42	84
51	3.0	2	90	90	180	42	42	84	51	3.0	2	96	96	192	42	42	84
52	5.0	2	90	90	180	42	42	84	52	5.0	2	96	96	192	42	42	84
53	7.0	2	90	90	180	42	42	84	53	7.0	2	96	96	192	42	42	84
54	9.0	2	90	90	180	42	42	84	54	9.0	2	96	96	192	42	42	84
55	11.0	2	90	90	180	42	42	84	55	11.0	2	96	96	192	42	42	84
56	13.0	2	90	90	180	42	42	84	56	13.0	2	96	96	192	42	42	84
57	15.0	2	90	90	180	42	42	84	57	15.0	2	96	96	192	42	42	84
58	17.0	2	90	90	180	42	42	84	58	17.0	2	96	96	192	42	42	84
	Consult Jon	113.5			324 81.5					Consult Jon	113.5						
										Mean temp.							
														1372	46		
														3567	44		
														4969	45		
														44.57°	44		
														6.5°			
																	3587

The current strength was 5×10^{-3} amperes so that the full deposit should be $5 \times 10^{-3} \times 1.135 \times 10^{-3} \times 1.2244 = 0.0695$ grammes. The actual amount was observed to be 730 or 5% greater.

Three of the bottles in the hot box and all three in the refrigerator were shunted. The current strength was found to have been excessive and the plates in the refrigerator were found to have smutted.

Measurement of Metre-Bottle Resistance.

No. of Plate	Weight 22.5.89	Weight 31.5.89	Gain	Loss	Gain of couple	Mean of gain + loss	Accepted total defl.	Res. of shunt	Total to temp.	W-w
1	54.455	55.191	0.736							
				0.720	0.006	0.723			∞	
2	55.566	54.836					0.730			
3	55.168	55.898	0.730						∞	
				0.725	0.005	0.728				
4	54.090	55.315								
5	52.660	53.092	0.432							
				0.425	0.007	0.429			2.11	0.201
6	54.645	54.220								
7	49.502	50.020	0.518							
				0.501	0.017	0.510			2.12	0.220
	54.921	54.420								
9	56.003	56.445	0.442							
				0.436	0.006	0.439			2.14	0.291
10	55.413	54.977								
11	35.178	34.927	0.257							
				0.251	0.006	0.254			4.19	0.476
12	54.962	55.219								
13	54.664	54.845	0.201							
				0.183	0.018	0.197			4.17	0.533
14	53.788	53.600								
15	53.000	53.351	0.351							
				0.349	0.002	0.350			4.20	0.380
16	54.424	54.075								

No. of plate	$\frac{W-w}{w}$	Res. of bottle	Mean	Mean Temp.
1				
2				
3				
4				
5	0.702	1.481		
6				
7	0.431	0.914	1.272 ω	31.4°C
8				
9	0.663	1.420		
10				
11	0.187	7.72		
12				
13	0.271	11.30	7.87 ω	6.5°C.
14				
15	0.109	4.58		
16				

Rough Calculation of the variation of the Earth's Potential ($\frac{dV}{dt}$) in time, on the supposition that the sun is an electrified body.

The e.m.f. required to break across air is about 100,000 volts for 3 cms. In a mile there are about 160,000 cms so that the culminating p.d. for a lightning flash one mile long is about 5000 million volts. Assuming that the sun possesses a potential of 1.0×10^{12} or a billion volts or 3.33×10^{9} abs. e.m.u. its capacity being 6.832×10^{11}, its charge would be 2.273×10^{13}. The apogee distance of the earth being given as 9.297×10^{7} miles $\times 1.6093 \times 10^{5} = 1.4961 \times 10^{13}$ and its perigee distance being 8.990×10^{7} $\times 1.6093 \times 10^{5} = 1.4462 \times 10^{13}$, the potential of the earth is respectively $\frac{2.273 \times 10^{13}}{1.4961 \times 10^{13}} = 1.831 \times 10^{6}$ and $\frac{2.273}{1.4462} \times 10^{6} = 1.576 \times 10^{6}$ ~~volts~~ abs e.m.u. and the difference 2.55×10^{5} units is spread over half a year or 1.578×10^{7} sec corresponding to a mean time rate of variation of potential equal to 1.616×10^{-2} or about 14.84 volts nearly 5 volts per sec.

Tests of a certain sample of Insulating Material supplied by Mr. Insull.

Four specimens of brown composition were received on the 3rd June. These had been moulded in a sweet-press.
One of these was left from 17 o'clock to 10 next morning on the hot plate of the day engine. Another was left to soak for the same period in water. The specimen was in the form of a dish was 4·2 (1⅝") diam by 0·9 (⅜") thick. Its res: between two plates of zinc after being wiped superficially dry was 10,000 ω under 9½ oz
(in the latter case the sp res would be 43,800 ω under pressure of 28 grammes 2500 ω - 27½ -
Weight of sample in damp state 27 grammes
hot and dried 24·14 "
The volume of this sample being 11·114 c.c.
Its sp. g: is 24·14/11·114 or 2·19 and its gain by soaking is 23·4 % by volume, in water or 10·5% by weight.
The material appeared to be practically uninflammable as it would not keep aflame after ignition by a bunsen burner even if in small chips.
After exposing for 2½ hours to water vapor rising from an evaporating basin, its weight rose to 24·6 gms. a gain of not quite 1% and the insulation fell slightly.
Acids do not seem to affect it greatly.

Trial of Paris Meters.

Six two wire meters intended for official tests at Paris were received from Bergmann & Co on Wednesday 5th June. They were set up for trial the same evening. The bottles were of the new pattern #4 size. The zinc was cast 5%. filed at the lower corners. The bottles were closed with corks. There were two bottles in each meter. The meters are designed for a deposit of one milligramme per ampere-hour and the resistances of copper and german silver wire were prepared on the values given at page 110.

The plates were all amalgamated hot and weighed after drying. It was observed in one instance that a hole having been overlooked in wiping off excessive amalgam the removal of a small quantity on the thread of the screw together with what was then brushed out amounted to nearly 30 mgms. The solution was 1·054 quite neutral. The six meters were joined in series with the two standards and the current of about 10 amperes put through them all at 22·30.

Carrying Power of Conductors.

Thursday June 6th

#11 Wire no. 12 BWG Diam. 0·109" covered to 0·176". Black-house wire.
0·2768cm 0·447cm Over [illegible]

Res. of galv 5360 = 2680 each side @ 68°F 19°C.

No. of Obs.	Obsch Rdg.	Constant	Sumner Dynm. Rdg.	Constant	Long range Galv rdg	Amplifier	Potentiometer Rdg.	Amplifier	Mercury Resistor rdg.	Amplifier	Time
1	0·800		5·5°		–		0·04495		0·04486	3·967	13 30/60
2	0·800								0·04486	3·967	13 35/60
3	1·000 (1)	0·193	12°	2·423	–		0·1020	8·408	0·1020	8·408	13 50/60
4	2·370 (2)	0·186	21°	2·767	–		0·1556	12·70	0·1557	12·73	13 55/60
5	3·150 (3)	0·182	39°	2·763	–		0·2116	17·27	0·2120	17·467	14 20/60
6	–		56·5°	2·958	2·00	20·25	0·2724	22·24	0·27424	22·40	14 35/60
7	–		76°	3·270	3·00	22·65	0·3267	26·67	0·3290	26·85	14 50/60
8	–		116°	3·040	4·05	30·[illegible]	0·4015	32·77	0·4017	32·79	14 55/60
9	–		131·7	2·969	4·5	33·[illegible]	0·4192	34·22	0·4222	34·46	15 25/60
10	–		155·5	3·023	5·0	35·42	0·4618	37·70	0·4615	37·67	15 35/60
11	–		194°	3·058	5·75	40	0·5217	42·59	0·5257	42·92	15 50/60
12	–		251°	3·062	6·16	44	0·5953	48·60	0·5926	48·38	16 20/60
13	–		287°	3·078	6·95	50	0·6244	51·14	0·6266	50·99	16 35/60
14	–		336·5°	3·036	7·5	55	0·6824	55·71	0·6823	55·70	16 50/60
15	–			6495	7·9	57	0·7222	58·96	0·7365	60·12	17 20/60
16			Mean	3·063	8·4	61	0·7872	64·26	0·7769	63·43	17 35/60
17					9·0	66·44	0·8440	68·90	0·8453	69·0	17 50/60
18					9·4	71	0·9060	73·96	0·9038	73·78	18 20/60

No. of Obs.	Res. in set with grating	Total res. grating side	Res. of wire	$\frac{R}{r}$	$\log \frac{R}{r}$	$\log \frac{R}{r}$ / 0·076018	Temp. air	Rise of temp.	$\log r$ − 2 log Lorenz	of resistance	Conductivity
1	4550	7230	0·07817				22°C		$\bar{2}$·25565	0·07902	
2	4540	7220 (1)	0·07819	1·001	0·000434	–			= 0·07816	÷ 0·07601	89·6%
3	4510	7190 (2)	0·07826	1·005	0·002166	1·29	0·1	0·31 1·2		÷ 615	
4	4450	7130 (3)	0·07842	1·014	0·00600	3·59		1·07 3·5		= 1761	
5	4425	7105 (4)	0·07849	1·018	0·00775	4·61	0·2	0·7 4·4			
6	4350	7030 (5)	0·07868	1·028	0·01199	7·13		2·2 6·9			
7	4265	6945 (6)	0·07891	1·041	0·01745	10·38	0·3	3·3 10·1			
8	4135	6815 (7)	0·07927	1·061	0·02572	15·29		4·8 15·0			
9	4000	6730 (8)	0·07951	1·074	0·03100	18·43	0·4	5·8 18·0			
10	3960	6640 (9)	0·07978	1·089	0·03703	22·02		7·1 21·6			
11	3812	6492 (10)	0·08023	1·113	0·05209	31·57	0·5	8·2 31·1			
12	3645	6325 (11)	0·08076	1·143	0·05805	34·52		10·0 34·6			
13	3500	6180 (12)	0·08125	1·170	0·06819	40·55	0·6	11·0 40·1			
14	3337	5017 (13)	0·08183	1·202	0·07990	47·51		12·9 46·9			
15	3176	5850 (14)	0·08245	1·235	0·09147	54·51	0·7	14·1 53·8			
16	2990	5670 (15)	0·08316	1·275	0·10551	62·73		15·6 62·			
17	2795	5475 (16)	0·08398	1·320	0·12057	71·70	0·8	17·2 70·9			
18	2600	5280 (17)	0·08487	1·369	0·13640	81·10	2300	18·8 80·2			

Carrying Capacity of Conductors.

June 7th Friday

Wire tested Black braided housewire covered Diam conductor + 11 B&S 14.160 cir. mm. 0.119" 0.302 mm. 0.165" 0.419

Res. of 9 2670 ω each side

No. of Obs.	Time	Obsd. Defl.	Const:	Sumaire Dynamo Rdg.	Constant	Clothworkers L.R. Galv.	Amperes	Potentiometer	816 Amperes	Mean Potentiometer Rdg.	1552 Amperes
1	15.30	1.005	0.192	4.5	2.45			0.0635	5.182	0.0635	5.182
2	15.$\frac{30}{35}$	+ "	0.220							0.0632	5.156
3	15.$\frac{40}{50}$	2.32	0.220	16.	2.64			0.1297	10.57	0.1308	10.67
4	15.$\frac{55}{16.00}$	3.02	0.191	31.7	2.80			0.1934	15.78	0.1923	15.69
5	16.$\frac{05}{10}$	—		44.5	2.99	1.77	19	0.2447	19.97	0.2454	20.02
6	16.$\frac{15}{20}$	.		113	3.06	4.0	29.63	0.3976	32.44	0.3977	32.46
7	16.$\frac{25}{30}$	.		217.5	3.107	5.95	49.2	0.5613	45.80	0.5607	45.76
8	16.$\frac{35}{40}$	.		311	3.08	7	49.22	0.6662	54.36	0.6710	54.76
9	16.$\frac{45}{50}$	.		—		8.2	58	0.7996	65.25	0.7958	64.93
10	16.$\frac{55}{17.00}$					9.4	71	0.9316	76.02	0.9315	76.02
11	17.$\frac{05}{10}$					10.2	79	1.0548	88.52	1.0896	88.94
12	17.$\frac{15}{20}$					11.2	90	1.2564	102.5	1.2574	102.3

No. of Obs.	Res. in cot. with glazing	Total Res. in glazing coils	Res. of wire	$\frac{R}{r}$	$\log \frac{R}{r}$	$\log \frac{S}{0.001618}$	Temp. air	°C Rise in wire	$\log r - 2.3 \log 1.00386$	sp. res. 0°C	conduct.
1	1670	4340	0.01537	1.			22°C.		5.17811 0.03700 5.14111 0.03324	0.01324 ×0.7163 ÷ 615	98.25%
2	1670	4340	0.01537	1.							
3	1650	4320	0.01574	1.0247	0.00926	1.21	0.1	0.7	1.		
4	1622	4292	0.01525	1.012	0.00518	3.08	0.2	2.9	2.9	1612	
5	1595	4265	0.01534	1.018	0.00775	4.61	0.3	4.3	4.3		
6	1485	4155	0.01575	1.045	0.01912	11.37	0.4	11.	11.		
7	1322	3992	0.01639	1.088	0.03663	21.78	0.5	21.3	21.3		
8	1152	3822	0.01712	1.136	0.05538	32.93	0.6	32.3	32.3		
9	980	3650	0.01793	1.190	0.07555	44.92	0.7	44.2	44.2		
10	715	3385	0.0193	1.281	0.10755	63.96	0.8	63.2	63.2		
11	492	3162	0.0207	1.373	0.13767	81.86	0.9	81.	81.		
12	220	2890	0.02264	1.502	0.17667	105.1	23°C	104.1	104.1		

Results of first test of Edison Meters for Paris Competition.

The meters were at work for 37 hours in all. The test was stopped at 9.0 8th June Saturday, plates dried and weighed with following results:—

No. of Plate	Weight 5. VI. 89	Sum: Pair Weight	Weight 8. VI. 89	Sum Pair Weight	Gain of Couple	Plate Loss	Plate Gain	Mean of Loss + Gain	Standard corrections	General Mean Embracing # 3	Ratio.
1	116.3860	234.4697	116.8316	234.4897	+0.0320	0.4326	0.4456	0.4391			
2	118.0915		117.6581								
3	117.7612	235.6957	117.9134	237.6938	−0.0019	0.1541	0.1522	0.1532			
4	117.9345		117.7804								
5	116.4787	240.3384	117.3644	240.3381	+0.0002	0.4485	0.4507	0.4496			1.007 07%
6	123.8222		122.9737								
7	115.5380	233.6391	116.2919	233.6372	−0.0019	0.4339	0.4358	0.4348			
8	117.7012		117.3453								
9	115.5362	232.0316	116.0054	232.0749	+0.0403	0.4289	0.4692	0.4491			
10	116.4954		116.0695								
11	116.9226	234.7191	117.3893	234.7438	+0.0247	0.4350	0.4597	0.4474		4474.2	0.994 −06%
12	117.7965		117.3615								0.994
13	116.6016	232.5614	117.0500	232.5679	+0.0065	0.4419	0.4484	0.4451			
14	115.9598		115.5179								
15	116.6105	234.1415	117.0703	234.1617	+0.0202	0.4396	0.4598	0.4497			
16	117.5310		117.0914								
17	117.7770	237.0446	118.2345	237.0657	+0.0213	0.4362	0.4675	0.4467			
18	119.2676		118.8312								
19	119.7560	235.6877	118.1910	235.6970	+0.0093	0.4287	0.4380	0.4334			0.970 −3%
20	115.9317		115.5030								
21	118.2260	237.4142	118.6761	237.4276	+0.0134	0.4387	0.4521	0.4454			
22	119.1902		118.7515								
23	115.4053	230.8021	115.8610	230.8211	+0.0190	0.4367	0.4557	0.4462			
24	115.3968		114.9601							4510	
25	81.9275	168.5938	81.9804	168.6055	+0.0117	0.5471	0.5588	0.5530	0.5520		
26	86.6663		87.2251								
Sum	168.5938		168.6055							0.5468	
27	82.9398	164.4119	85.4734	164.3855	−0.0234	0.5560		0.5443	0.5445	= 1116.8	
28	79.4721		78.9161							aup. Inc.	
Pair	164.4135		164.3874				0.5326				

The solution was quite neutral

The mean couple gain is 14 mgms or 7 per plate

No. 3/4 bottle was found short circuited by a screw that had been missing and which rusted on the copper strips.

No. 19 plate was the only one that smutted. No reason could be assigned.

The mean error is 0.6% deficit

max: deficit 3%

" excess 0.7%.

These meters were set on a second test 10th June the solution being very slightly acid. (1 drop).

By this formula when $x = 12$ $X = 15.15$ $R = 7.03$ $r = 4.98$ $bh = 6.32$

$$C = \frac{6.32\,H}{6.283}\left\{\frac{1}{15.15\,\log_e\frac{7.03+16.7}{4.98+18.95} - 12\,\log_e\frac{7.03+19}{4.98+13}}\right.$$

$\frac{23.73}{20.93}$	$\frac{20.93}{17.98}$
1.1344	1.1644
$M \times 0.054461$	$M \times 0.06575$
$\bar{3}.73727$	$\bar{3}.81921$
$\frac{43439}{\bar{1}.17156}$	$\frac{.14324}{\bar{1}.35596}$
.14824	0.1793
2.2248 —	2.152

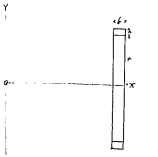
0.096

$$= \frac{6.32 \times 0.19 \times 10 \times 10.42}{6.283} = \frac{6.32 \times 1.9 \times 1.0042 \times 10^1}{6.283} = 19.92$$

By the shorter and less accurate method $= 20.28$

Error of latter in excess 1.8% = maximum error

Investigation of the Degree of Error in the use of the Long Range Ammeter at short ranges.



Let R and r be the ext: and int: radii of the ring and $R = r + b$

- b = the breadth of the ring.
- the axis of the ring be the x axis.
- at O let a magnet be placed of negligible length and unit pole strength.

Then if the current circulating in the coil be C and the area of the ring $= bh$ then the current per unit area $= \frac{C}{bh} = c$

The force exerted by any elementary rectangular ring of coordinates in section x and y will be horizontally at O

$$df = \frac{2\pi c\, y^2}{(x^2+y^2)^{\frac{3}{2}}} \quad \text{so that the whole force exerted is}$$

$$f = 2\pi c \int_r^{r+b}\int_x^{x+b} \frac{y^2\,dx\,dy}{(x^2+y^2)^{\frac{3}{2}}}$$

$$dy\,y^2\int_x^{x+b}\frac{dx}{(x^2+y^2)^{\frac{3}{2}}} = y^2\,dy\left[\frac{x}{y^2\sqrt{x^2+y^2}}\right]_x^{x+b} = dy\left\{\frac{x+b}{\sqrt{(x+b)^2+y^2}} - \frac{x}{\sqrt{x^2+y^2}}\right\}$$

$$\text{let } \left.\begin{array}{l} x+b = f \\ x \quad = g \end{array}\right\} \therefore\ f = 2\pi c\int_r^{r+b}\left\{\frac{f}{\sqrt{f^2+y^2}} - \frac{g}{\sqrt{g^2+y^2}}\right\}dy$$

$$= 2\pi c f\int_r^{r+b}\frac{dy}{\sqrt{f^2+y^2}} - 2\pi c g\int_r^{r+b}\frac{dy}{\sqrt{g^2+y^2}}$$

$$= 2\pi c f\left[\log_e\left(y+\sqrt{f^2+y^2}\right)\right]_r^{r+b} - 2\pi c g\left[\log_e\left(y+\sqrt{g^2+y^2}\right)\right]_r^{r+b}$$

$$= 2\pi c\left\{f\log\frac{R+\sqrt{f^2+R^2}}{r+\sqrt{f^2+r^2}} - g\log_e\frac{R+\sqrt{g^2+R^2}}{r+\sqrt{g^2+r^2}}\right\}$$

$$= 2\pi c\left\{X\log_e\frac{R+\sqrt{X^2+R^2}}{r+\sqrt{X^2+r^2}} - x\log_e\frac{R+\sqrt{x^2+R^2}}{r+\sqrt{x^2+r^2}}\right\}$$

balancing against H

$$C = \frac{bh\,H}{2\pi}\left\{\frac{1}{X\log_e\frac{R+\sqrt{X^2+R^2}}{r+\sqrt{X^2+r^2}} - x\log_e\frac{R+\sqrt{x^2+R^2}}{r+\sqrt{x^2+r^2}}}\right\}$$

For an ordinary tangent galvo $x = -X$

$$\text{whence } C = \frac{bh\,H}{2\pi}\left\{\frac{1}{+2X\log_e\frac{R+\sqrt{X^2+R^2}}{r+\sqrt{X^2+r^2}}}\right.$$

$$= \frac{2\beta h\,H}{4\pi X}\,\frac{1}{\log_e\frac{R+\sqrt{X^2+R^2}}{r+\sqrt{X^2+r^2}}} \quad \text{let } b = 2\beta$$

$$= \frac{2\beta h\,H}{4\pi\beta}\,\frac{1}{\log_e\frac{R+\sqrt{\beta^2+R^2}}{r+\sqrt{\beta^2+r^2}}}$$

$$= \frac{hH}{2\pi\beta}\times\frac{1}{\frac{1}{h}\log_e\frac{R+\sqrt{\beta^2+R^2}}{r+\sqrt{\beta^2+r^2}}}$$

If there are N turns in the space $2\beta h$ we have $Nc = C$ $\therefore C = \frac{C}{N}$

$$\text{current in each turn} = \frac{H\tan\theta}{2\pi N\,\frac{1}{h}\log_e\frac{R+\sqrt{\beta^2+R^2}}{r+\sqrt{\beta^2+r^2}}}$$

No. of obs.	sp. res. obsd.	sp. res. calculated z	$z-M$ v	v^2	Σv^2	$\sqrt{\frac{\Sigma v^2}{n-3}}$	$\cdot 6745\sqrt{\frac{M}{L}}$	r				
1	31·10	30·92	− 0·18	0. 0324								
2	26·36	26·35	− 0·01	·0001								
3	23·88	24·11	+ 0·23	·0529		$\sqrt{0\cdot0302}$						
4	22·76	22·88	+ 0·12	·0144	0·1209	= 0·1774	0·117	± 0·12.				
5	20·45	20·34	− 0·11	·0121								
6	18·62	18·53	− 0·09	·0081								
7	15·86	15·89	+ 0·03	·0009								

(20)

Comparison of Von Beta's Determination of the sp. res. of $In\,SO_4$ solution with those made here.

From series #3 of his results, subsequently mentioned to have been a good one, and with the sp. res. of pure Hg: as 0·9534 also the legal ohm as 0·9887 BA u we have from page 9 Vol CXIII Pogg Ann. Phys. Observations equivalent as far as 53°C

$$
\begin{aligned}
a + 15\cdot7\,b + 246\cdot5\,c &= 31\cdot10 & \qquad 15\cdot7a + 246\cdot5b + 3869\cdot9c &= 488\cdot27\\
a + 23\cdot5\,b + 552\cdot3\,c &= 26\cdot36 & \qquad 23\cdot5b + 552\cdot3b + 12977\cdot9c &= 619\cdot46\\
a + 27\cdot8\,b + 772\cdot8\,c &= 23\cdot88 & \qquad 27\cdot8a + 772\cdot8b + 21485\cdot0c &= 663\cdot86\\
a + 30\cdot4\,b + 924\cdot2\,c &= 22\cdot76 & \qquad 30\cdot4a + 924\cdot2b + 28094\cdot5c &= 691\cdot90\\
a + 36\cdot6\,b + 1339\cdot6\,c &= 20\cdot45 & \qquad 36\cdot6a + 1339\cdot6b + 49027\cdot9c &= 748\cdot47\\
a + 41\cdot9\,b + 1755\cdot6\,c &= 18\cdot62 & \qquad 41\cdot9a + 1755\cdot6b + 73560\cdot1c &= 780\cdot17\\
a + 53\cdot3\,b + 2840\cdot9\,c &= 15\cdot86 & \qquad 53\cdot3a + 2840\cdot9b + 151419\cdot4c &= 845\cdot33.\\
\hline
7a + 229\cdot2\,b + 8431\cdot9\,c &= 159\cdot03 & \qquad 229\cdot2a + 8431\cdot9b + 340434\cdot7c &= 4837\cdot46
\end{aligned}
$$

$$
\begin{aligned}
246\cdot5a + 3869\cdot9b + 60800c &= 7666\cdot2\\
552\cdot3a + 12977\cdot9b + 305000c &= 14558\cdot6\\
772\cdot8a + 21485\cdot0b + 597000c &= 18454\cdot6\\
924\cdot2a + 28094\cdot5b + 850400c &= 21832\cdot8\\
1339\cdot6a + 49027\cdot9b + 1795600c &= 27394\cdot5\\
1755\cdot6a + 73560\cdot1b + 3080000c &= 32869\cdot3\\
2840\cdot9a + 151419\cdot4b + 8664000c &= 45056\cdot7\\
\hline
8431\cdot9a + 340434\cdot7b + 14758400c &= 166855.
\end{aligned}
$$

So that the normal equations

$$
\begin{aligned}
7a + 229\cdot2b + 8432c &= 159\cdot0 \qquad (1)\\
229\cdot2a + 8431\cdot9b + 340435c &= 4837\cdot5 \qquad (2)\\
8431\cdot9a + 340435b + 14758400c &= 166855 \qquad (3)
\end{aligned}
$$

From (1) $\quad a = 159/7 - 229\cdot2b/7 - 8432c/7 = 22\cdot71 - 32\cdot75b - 1204\cdot6c$

" (2) $\quad 5205 - 7506b - 276100c$
$\quad + 8432\cdot b + 340440c = 4838 \Big\} \; 926b + 4435c = -367 \quad (a)$

" (3) $\quad 191490 - 2761500b - 10159000c$
$\quad + 340435b + 14758400c = 166855 \Big\} \; 64285b + 4599400c = -24635$

" (4) $\quad b = \dfrac{-367}{926} - \dfrac{4435c}{926} = -0\cdot3964 - 4\cdot9c$

" (5) $\quad -254824 - 4467000b +$
$\quad + 4599400c = -24635 \Big\} \; 132400c = 849 \quad (b)$

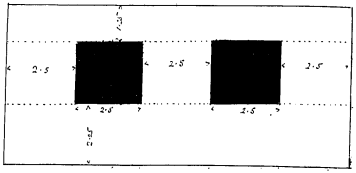
" (6) $\quad c = 0\cdot006411$

" $\quad b = -0\cdot44456 - 0\cdot3964 = -0\cdot84420$

" $\quad a = 22\cdot71 + 27\cdot57 - 7\cdot72 = 42\cdot56$

Check. $\quad 8432 \times 42\cdot56 + 340435 \times -0\cdot84420 + 14758400 \times 0\cdot006411 = 166855 = 0$
$\quad 358850 - 286600 + 94850 - 166855 = +25$

$$
\begin{aligned}
42\cdot56 + 15\cdot7 \times 0\cdot8442 + 246\cdot5 \times 0\cdot006411 &= 42\cdot56 \quad v \\
42\cdot56 + 23\cdot5 + 552\cdot3 &\quad -13\cdot22 + 15\cdot58 = 30\cdot92 - 0\cdot19\\
42\cdot56 + 27\cdot8 + 772\cdot8 &\quad -19\cdot75 + 3\cdot54 = 26\cdot35 - 0\cdot01\\
42\cdot56 + 30\cdot4 + 924\cdot2 &\quad -23\cdot40 + 4\cdot95 = 24\cdot11 + 0\cdot23\\
42\cdot56 + 36\cdot6 + 1339\cdot6 &\quad -25\cdot60 + 5\cdot92 = 22\cdot88 + 0\cdot12\\
42\cdot56 + 41\cdot9 + 1755\cdot6 &\quad -30\cdot91 + 8\cdot59 = 20\cdot34 - 0\cdot11\\
42\cdot56 + 53\cdot3 + 2840\cdot9 &\quad -35\cdot28 + 11\cdot25 = 18\cdot53 - 0\cdot09\\
&\quad -44\cdot88 + 18\cdot21 = 15\cdot89 - 0\cdot03
\end{aligned}
$$



Carrying Capacity of Conductors.

June 12th Wednesday.

Abandoned the wooden casing hitherto used in favor of a larger one whose dimensions are as follows –

Length 60 cms Breadth 12.5 height 5.75.

Placed in it both the specimens last tested and a black horse-wire diam: 0.163" = 0.4114cm covered to 0.228" = 0.579 # 8 B.W.G.

Res: of gales 53 gos = 27.00 T.B. 24°C. T.g. 23.3°C.

No of Obs.	Time	Shunt	Coarse	L. R. Am	Fine	Potentio	Amperes	Mean Potentio Reg.	Amperes	Res: in est with #11 wire	Total Res gauging side	Res: of #11
1	13.35	1.05		–		0.06444	5.265	0.0643	5.247	1690	12.90	0.01507
2	.35	1.96				0.1227	10.01	0.1222	9.97	1670	12.70	0.01574
3	.40	2.90				0.1900	15.51	0.1912	15.60	1660	12.60	0.01521
4	.40									1610	12.10	0.01385
5	.45			1.95		0.2682	21.28	0.2890	21.13	1580	12.80	0.01526
6	.45			2.90		0.3089	25.21	0.3102	25.32	1525	12.25	0.01666
7	.45			4.25		0.3778	30.83	0.3774	30.80	1470	12.70	0.01556
8	.45			5.7		0.5020	41.04	0.5033	41.07	1322	10.27	0.01622
9	.45			7.1		0.6206	50.65	0.6172	50.37	1187	28.87	0.01701
10	.50			8.45		0.7576	61.82	0.7585	61.89	965	36.65	0.01800
11	.50			9.86		0.9138	74.56	0.9058	73.92	722	31.22	0.01933
12	.50			10.8		1.0174	85.45	1.0182	83.08	532	32.32	0.02047
13	.50			11.2		1.1204	91.42	1.1210	91.47	322	30.22	0.02159
14	.50			12.25		1.2516	102.1	1.2440	103.2	96	27.96	0.02366
15	.50			13.22		1.4064	114.2	1.4226	116.9	–	–	
16	.50			13.6		1.500	122.4	1.4562	122.1	–	–	
				14.14		1.6158	131.8	1.6210	132.3	–	–	
				20.96								

No of Obs.	R/F	log R/F	Res: in est with Platinum #8 B.W.G.	Total Res gauging side	Res: of No 8	R/F	log R/F corrected	Temp: air	°C. rise for #11	°C. rise for #8 wire	Rise with for bank resistance	
1	1.005	0.02217	5870	8270	0.007998	1.000	0.	22.8	1.29	0.5.11	1.2	0.4
2	1.009	0.00359	5550	8220	0.008018	1.002	0.00446	·1	2.31	1.55	2.1	1.44
3	1.019	0.00917	5525	8225	0.008043	1.006	0.00260	·2	4.86	2.57	4.6	2.3
4	1.026	0.01115	5485	8185	0.008091	1.010	0.00422	·3	6.63	3.85	6.2	3.5
5	1.039	0.01662	5450	8150	0.008115	1.015	0.00647	·4	9.88	5.88	9.4	5.4
6	1.052	0.02202	5385	8085	0.008181	1.023	0.00988	·5	13.10	9.63	12.5	9.0
7	1.070	0.02943	5270	7970	0.008302	1.038	0.01620	·6	22.26	11.44	21.6	12.7
8	1.120	0.05308	5120	7820	0.008458	1.0878	0.02628	·7	31.57	19.87	30.8	19.1
9	1.198	0.07846	4965	7660	0.008686	1.080	0.03342	·8	46.66	32.47	45.8	31.6
10	1.283	0.10823	4690	7290	0.009074	1.134	0.05461	·9	64.35	36.1	63.4	35.1
11	1.359	0.13322	4490	7190	0.009200	1.150	0.06070	1·0	79.22	46.0	78.1	44.9
12	1.453	0.16227	4217	6917	0.009562	1.195	0.07737	1·1	96.8	55.34	95.3	54.7
13	1.570	0.19590	3975	6675	0.009912	1.239	0.09307	1·2	116.5	71.1	115.3	69.9
14			3580	6280	0.01053	1.317	0.11959	1·3		81.3		80.1
15			3335	6035	0.01096	1.370	0.13672	1·4		92.36		91.2
16			3080	5780	0.01144	1.430	0.15534	2·4				

v	
−0.0065	
−0.0047	
−0.0002	
−0.0049	
+0.0035	
+0.0003	
+0.0047	
−0.0016	
+0.0007	
−0.0006	
+0.0013	
Mean	362/11 = −0.0033

Test of Paris Meters (2nd Trial)

Results of 2nd trial of meters with very slightly acid solution. Otherwise the same conditions. Test commenced 16.—10. VI and lasted just 48 hours.

No. of plate	Weight 10. VI. 89.	Couple weight	Weight 13. VI. 89	Couple weight	Couple Gain	Plate Loss	Plate Gain	Mean Loss or Gain	Standard correction	General Mean	
1	117.2968	233.9714	117.7212	233.9622	−0.0032	*					
2	116.6746		116.2470			0.4276	0.4224	0.4260			
3	115.2759	224.8257	115.6902	224.2203	−0.0054						
4	109.5528		109.1299			0.4229	0.4175	0.4202			
5	116.4040	231.4789	115.9948	231.4758	−0.0031						
6	115.0749		115.6910			0.4192	0.4161	0.4177			
7	116.8020	232.7080	117.2254	232.7100	+0.0020						
8	115.9060		115.4846			0.4214	0.4234	0.4224			
9	122.1896	227.4888	122.6011	237.4135	−0.0053						
10	115.2992		114.8124			0.4168	0.4115	0.4142			
11	117.3022	236.1677	117.7199	236.1661	−0.0016						
12	118.8632		118.4462			0.4173	0.4157	0.4165			
13	117.4866	234.5575	117.8961	234.5522	−0.0053						
14	117.0709		116.6561			0.4148	0.4095	0.4122		417.5	0.9782
15	114.9771	233.6126	115.3275	233.6073	−0.0047						
16	118.6349		118.2798			0.4151	0.4104	0.4128			
17	116.0605	232.8696	116.4767	232.8634	−0.0062						
18	116.8091		116.3867			0.4224	0.4162	0.4193			
19	116.5989	232.8839	116.9201	232.8768	−0.0071						
20	116.3750		115.9567			0.4183	0.4112	0.4148			
21	115.1630	232.9014	115.5799	231.9990	−0.0024						
22	116.8384		116.4191			0.4193	0.4169	0.4181			
23	117.9267	233.8267	118.3100	233.8209	−0.0058						
24	115.9000		115.4809			0.4191	0.4133	0.4162			
25	85.8542	163.5442	86.2718	163.5335	−0.0107						
26	77.6900		77.1617			0.5283	0.5176	0.5230	.5241	428.2	
	163.5442									426.8	
27	80.8348	163.3319	80.3135	164.3218	−0.0071						
28	83.4971		84.0113			0.5213	0.5142	0.5178	0.5206	425.41	
	164.3326				0.0659						
					0.0481						
					.0014						

The solution was prepared in this case by adding 8 drops of c.p. conc: H_2SO_4 to the gallon of sol: The density of current was $\frac{426.8}{48}$ = 9 ampères approximately. The mean loss per plate was 0.002 gm the mean error 2.2%, the mean deviation 3.3 mgms from the mean and taking the plates 25 to 26 of last test together with the results 25-26 27-28 in this, we have the constant 1.015

Trial of Ag_2S cut-outs for Municipal lamps.

Thin rolled strip of Ag_2S prepared by the action of H_2S on $AgNO_3$ and the precipitate fused in a crucible under hydrogen. The resistance of these strips is exceedingly high, to a p.d. of only 2 or few volts but breaks down very rapidly under either heat or e.m.f. say of 100 volts. These cut outs seem to take practically no current from municipal lamps when used as shunts.

Carrying Capacity of Conductors.

Wires tested #10 bare soft copper Schenectady wire 0·13145" 613 cmm. 0·3416 cmm
#8 - - - - - 0·16142" 0·4170

Res: of galv: 5415 ω T.B. 22·5°C. = 2705 ω on each side ~~TTT~~.
Both halves of grating in parallel = 0·01225 ω.

No of Obs	Time	L.A. Ammeter	Amperes	Potentio Rdg	Amperes	Mean Potentio Rdg.	16·33 Amperes	Res: in cct with grating	Total Res: in cct with grating	3273 Total Res in #8 wire	R/r	Rise Temp.
1	16 49/55					0·0752	12·28	14·00	4105	0·088070		
2	16 57/100					0·12024	19·65	1397	4102	0·088076	1·001	-
3	17 57/70					0·1900	31·02	1370	4075	0·088130	1·0072	1·85
4	·18/20	6·75	47·	0·3112	50·8	0·3132	51·14	1195	3900	0·085498	1·053	13·6
5	·30/20	8·7	64	0·44293	71·73	0·44413	72·05	905	3610	0·079178	1·137	25·3
6	·30/20	10·15	77	0·5555	90·68	0·5517	90·66	660	3365	0·078245	1·220	36·55
7	·48/30	13·9	126	0·7716	126·0	0·7709	125·5	60	2765	0·07198	1·485	124·7
8												

No of Obs	Res: in cct with grating	Total Res: in #8 wire	Res: of #10 wire	R/r	Rise of Temp °C	Temp in	Rise of #10 wire	Rise of #8 wire	Res: of #10 @ 0°C.	Res: of #8 @ 0°C.	Sp. res	
1	-2·5	2680	0·01214			25°			25 × 0·014 = 0·1		0·01103 × 0·0426 = 613	0·0426 × 613
2	-7	2698	0·01222	1·007	1·8	0·1	1·7	2·7	0·01214 + 0·1	0·0080704		
3	35	2740	0·01241	1·022	5·66	0·2	5·6	3·0 1·8	= 0·01103	= 0·007336	= 16148	1628
4	277	2982	0·01350	1·112	28·8	0·3	28·6	2·1 13·3				
5	647	3552	0·01609	1·325	83·55	0·4	83·3	2·1 34·8				
6	1060	3765	0·01705	1·404	103·9	25·6	103·4	2·1 56·				
7	-	-						124·				
8												

Comparison of the two standard meters before sending them to Paterson N.J. 14th June 82

Res: both cils galv 5415 ω @ 22·5°C.

Temp. std copy 0·1 C.w. @ 25·5°C.

Res: added to std: side 20 ω. for 0·09945 meter shunt = 0·09925 × 0·10015 ω
- - - - - 10 ω. . 0·09980 - - 0·09963 × 0·10015 ω

= 0·09944 ω and 0·09978 ω respectively.
difference of 5 and 2 parts in 10,000 ω.

Res: of 0·09945 spool = 97·88 ω
- - 0·09980 . = 98·33 ω @ 22·5°C T.B.

On the specific resistance of metals.

Kemper in his Handbook of Elec. Testing 4th Ed p 4114 states that on the authority of Matthiessen the res: of a pure copper wire rises with the temperature according to the compound interest law: i.e. logarithmically. This statement does not seem to be borne out on an examination of Matthiessen's publications for on page 25 Phil Trans 1862 part 1 Table XII there appear the final values for the rise in res: of four copper wires –

0°C	100
20°C.	107.97
40°	116.33
60	124.98
80°	133.69
100°	142.22

If the logarithmic law held, taking $\log 1.0797 = 0.03330 \times 5 = 0.01665 = \log 146.72$. a very decided discrepancy in excess

But if $r = x + yt + zt^2$

$$\frac{dr}{dt} = y + 2zt$$

from this $y = 0.003955$ and $z = 0.000\,001\,481$

With the formula $r = x + 0.003955t + 0.000\,001\,481\,t^2$

we have @ −100°C $\frac{dr}{dt} = 0.003955 - 0.000296 = 0.003659$

" " @ 0°C $\frac{dr}{dt} = 0.003955$

" " @ 100°C " $= 0.003955 + 0.000296 = 0.004251$

" " @ 200°C $= 0.003955 + 0.00296 = 0.006915$

For this treatment of the problem the curve of res as ordinate to temp: as abscissa is always rising convex to the temp. but with Matthiessen's general equation $\lambda = 99.137 - 0.37675t + 0.000\,017\,456t^2$

$$\frac{d\lambda}{dt} = -0.37675 + 0.000\,017\,456\,t \quad \therefore \text{ when } t = \frac{.37675}{.000\,017\,456} = \frac{3.765 \times 10^{-1}}{1.746 \times 10^{-5}} = 215.7$$

λ is a minimum and again increases

or taking even $\lambda = 99.137 - 0.39201\,t + 0.000\,123\,18t^2 - 0.000\,000\,193\,t^3$

then λ = conductivity $\frac{d\lambda}{dt} = -0.39201 + 0.000\,246\,36t - 0.000\,000\,579\,t^2$

when $t = 314.5$°C a similar inflection takes place.

Judging from Dr Siemens' experimental results these final conductivity formulae are inadequate to express the general law. Taking Siemens' law for copper

$$r = 0.026577\sqrt{T} + 0.003\,144\,43\,T - 0.29751$$

we have $\frac{dr}{dt} = 0.089331\sqrt{T} + 0.010569\,T - 1$ as simplified from

and $\frac{dr}{dt} = 0.012\,8885\,T^{-\frac{1}{2}} + 0.003\,144\,43$

$$\frac{d^2r}{dt^2} = -0.006\,644\,43\,T^{-\frac{3}{2}}$$

for $T = 274$	$t = 0$	$\frac{dr}{dt} = 0.003\,989$	Mean 0° to 100°	0.00389
" $T = 374$	$t = 100$	$= 0.00383$		
" $T = 216$	$t = -58$	$= 0.004\,07$	" 0° to −58°	0.1400 given by 8.18 = 0.1415
" $T = 205$	$t = -69$	$= 0.004\,07$	" −69 to −123	0.415 given by 2.18 = 0.425
" $T = 151$	$t = -123$	$= 0.004\,22$		

Siemens' formula agrees with Matthiessen well + with Bullett + Beaty very fairly.

For now Siemens' law is $r = 0.072545\,T^{\frac{1}{2}} + 0.003\,8133\,T - 1.23971$

$$\frac{dr}{dt} = 0.02926\,T^{-\frac{1}{2}} + 0.003076$$

for $T = 274$ $t = 0$ $\frac{dr}{dt} = 0.004\,84$

" $T = 182$ $t = -92$ " $= 0.005\,14$

mean calculated value for range +9 to −92 = 0.489

Bullett + Beaty gui = 0.490.

Calibration of an Ammeter for Alternating Currents.

Received on the 15th June from Messrs Bergmann & Co. an ammeter without scale for calibration with alternating current of 200 to 300 alternations per sec.. The speed of the dynamo was 2160 revs per min = 35.8 × 8 = 286.4 alts per sec.

Calibrated the Cardew voltmeter as follows:—

Degrees	25	30	35	40	45	50	55	60	65	70	75	80
Volts	39.19	43.36	45.65	50.40	55.16	57.90	59.30	63.70	67.39	70.33	72.80	76.35
Δv / $\Delta\theta$		0.834	0.46	0.95	0.95	0.75	0.28	0.88	0.74	0.59	0.50	0.71
85	90	95	100	105	110	115	120	125	130	135	140	145
79.41	82.37	85.42	88.52	91.75	94.30	97.38	101.00	104.00	105.92	109.56	112.12	114.62
0.61	0.40	0.61	0.62	0.65	0.57	0.62	0.72	0.60	0.38	0.73	0.52	0.50

Stretched some 234.00 cms of thin platinoid wire 0.012" = 0.031 cm having a bot res: of 126.4 ω in five lengths up and down the 600 cm bench and with the ammeter in cct: observed the volts p.d. on this and other known resistances of 60, 90, & 120 ω also 1000 & 500 ω in a res: box... 10% being deducted from the cardew reading gave the mean emf in volts on the wire and this divided by the res gave the current. Several different readings on different resistances agreed very fairly.

After calibrating the scale from 0, 0.05, 0.1 to 1.45 in hundredths found that a current of 0.5 amperes continuous gave a reading of 0.2375 and a current of 1.0 ampere a reading of 0.87

Res: of apparatus about 1.9 ω

Comparison of resistances. 18th June. Differential Galvo:

Res: of Galvo 2702 + 27 × 0.03 × 5 = 2706 T.G. 24.2°.

Std. Legal Ohm @ 23.9° C correct at 15.5 = 8.4 × 0.0003 = 0.0025 ω.

Res: added to 0.1 ω 900 when 9000 : $\frac{1000 \times 2706}{2706}$ :: 9000 : 720.2 = 0.0252 ω equiv.

$\frac{0.00252 \times 3606}{2706}$ = 0.10002 ω @ 23.5° C.

With another 1000 obtained balance at 897 and a third 898 taking latter we have 0.1002 ω @ 23.5° C. = 0.1000 @ 15° C.

with legal Ohm and Copy) 0.01 ω Balance at 4.0 ω with 9900 : $\frac{100 \times 2706}{2706}$ results in 9900 : 96.43 :: $\frac{1.0025 \times 96.43}{9996.43}$ = 0.009672 equivalent

$\frac{0.009672 \times 2706}{2700}$ = 0.009836 ω @ 23.5° C.

With 0.1 and 0.01 copies added res: to 0.01 830 ω. } Wt 2 } 0.009833 @ 23.5°C. Wt

$\frac{0.1002 \times 730.2}{9730.2}$ = $\frac{0.00752 \times 3536}{2706}$ = 0.009826 ω @ 23.5°

With 0.01 and grating balance 615 ω on grating

$\frac{0.009833 \times 33.19}{2706}$ = 0.012006 ω

With 0.01 ω and large shunt for 1000 ampere balance 13750 ω on 0.01 ω

$\frac{0.009833 \times 2706}{16652}$ = 0.001615 ω } Wt 2 } 0.001627 Wt 1

With grating and large shunt balance 17030 on grating

$\frac{0.009833 \times}{0.012006 \times 2702}$ = $\frac{0.012006 \times 2702}{17732}$ = 0.001651

Carrying Capacity of Conductors.

June 15th Saturday)
2 samples of bare copper wire from Schenectady)
#6 BWG 0.203" by micrometer 1.5[illegible]ohm
#4 BWG 0.239" " " 1.97[illegible]-1.60)
Res. of grating 0.0121 " Res. galv 2735

Test No.	Time	Ammeter	Amperes	Potentiometer	Amperes	15.5 Mean Potentiometer Reading	Amperes	Res. in cct with grating #6	Total Res. for grating side	22.5 Res. of #6 6	$\frac{R}{r}$ #6
1	$10\frac{25}{40}$					0.0362	5.983	3870	6605	0.00501	1.000
2	$\frac{15}{30}$					0.0634	10.480	3800	6535	0.005063	1.0105
3	$\frac{20}{30}$	2.80	24	0.1577	26.06	0.1600	26.444	3705	6440	0.005139	1.0260
4	$\frac{15}{40}$	5.35	37	0.2512	41.52	0.2535	41.90	3585	6320	0.005226	1.0145
5	$\frac{45}{50}$	7.2	51	0.3439	56.85	0.3356	55.47	3430	6165	0.005367	1.071
6	$11\frac{50}{100}$	9.05	67	0.4386	72.50	0.4411	72.89	3190	5925	0.005581	1.114
7	$\frac{55}{70}$	10.10	77	0.5150	85.12	0.5110	84.20	3070	5745	0.005760	1.150
8	$\frac{45}{50}$	11.55	95	0.6200	102.2	0.6311	104.30	2700	5435	0.006059	1.215
9	$\frac{30}{50}$	12.55	107	0.7072	116.9	0.7191	118.85	2415	5150	0.006425	1.282
10	$\frac{30}{40}$	13.80	125	0.8160	134.9	0.8196	135.5	2040	#775	0.006920	1.383
11	$\frac{55}{55}$	14.60	132	0.9010	148.9	0.9394	155.3	1620	4355	0.007600	1.577
12	$11\frac{50}{12.00}$	15.9	158	1.0396	171.8	1.0586	173.6	1210	3945	0.008389	1.674

No. of Obs.	Res. in cct with grating	Total Res. grating side	Res. of #4	$\frac{R}{r}$ #4	Rise of temp. of #6	Rise of temp. of #4	Temp. air	Rise of #6	Rise of #4		
1	6370	9105	0.003627	1.			27°				
2	6285	9020	0.003668	1.011	2.70	2.83		2.7	2.8		
3	6130	8865	0.003733	1.029	6.68	7.45		6.7	7.5		
4	6030	8765	0.003776	1.041	11.57	10.54		11.6	10.5		
5	5890	8625	0.003837	1.058	18.25	14.91		18.3	14.9		
6	5770	8405	0.003938	1.086	29.3	22.11		29.3	22.11		
7	5470	8205	0.004033	1.112	38.56	28.79		38.6	28.8		
8	5190	7925	0.004176	1.151	55.27	38.82		55.3	38.8		
9	4865	7600	0.004357	1.200	72.50	51.41		72.5	51.4		
10	4500	7235	0.004574	1.261	98.46	67.09		98.5	67.1		
11	4020	6755	0.004899	1.351	132.9	90.21		132.9	90.2		
12	3600	6335	0.005224	1.440	173.2	113.1	27°	173.2	113.1		

$$a = \frac{-0.2 + 2.5 + 0.6}{n} \quad \frac{+0.85}{20} = \pm 0.0425$$

Division	Correction
0°	-0.2
5°	$-0.2 = (-0.02) + 0.0425 = -0.1375$
10°	$+0.085 - 0.2 + (-0.01) = -0.20 + 0.075 = -0.125$
15°	$+0.1275 - 0.2 - (-0.01) = -0.200 + 0.0375 = -0.0625$
20°	$+0.1700 - 0.2 - (+0.06) = -0.26 + 0.17 = -0.09$
25°	$+0.2125 - 0.2 - (+0.11) = -0.31 + 0.2125 = -0.0975$
30°	$+0.2550 - 0.2 - (+0.07) = -0.27 + 0.2550 = -0.015$
35°	$+0.2975 - 0.2 - (+0.09) = -0.29 + 0.2975 = +0.0075$
40°	$+0.3400 - 0.2 - (+0.09) = -0.29 + 0.3400 = +0.0500$
45°	$+0.3825 - 0.2 - (\pm 0.09) = -0.29 + 0.3825 = +0.0925$
50°	$+0.4250 - 0.2 - (+0.12) = -0.32 + 0.4250 = +0.1050$
55°	$+0.4675 - 0.2 - (+0.10) = -0.30 + 0.4675 = +0.1675$
60°	$+0.5100 - 0.2 - (+0.10) = -0.30 + 0.5100 = +0.2100$
65°	$+0.5525 - 0.2 - (+0.10) = -0.30 + 0.5525 = +0.2525$
70°	$+0.5950 - 0.2 - (-0.03) = -0.2 + 0.5950 = +0.4250$
75°	$+0.6375 - 0.2 - (-0.04) = -0.2 + 0.6375 = +0.4375$
80°	$+0.6800 - 0.2 - (-0.02) = -0.2 + 0.7000 = +0.5000$
85°	$+0.7225 - 0.2 - (+0.03) = -0.23 + 0.7225 = +0.5000$
90°	$+0.7650 - 0.2 - (+0.02) = -0.22 + 0.7650 = +0.5450$
95°	$+0.8075 - 0.2 - (+0.02) = -0.22 + 0.8075 = +0.5875$
100°	$+0.8425 - 0.2 - (+0.05) = -0.25 + 0.8425 = +0.5925$

Calibration of Standard Thermometer.

Inserted Standard Thermometers #1 and 2 also the three other Fahr Thermometers #3 4 + 5 in crushed ice that had been washed with tap water.

#1 and 2	indicated	0.1 +
#3	-	0.5°F +
#4	-	2.0°F +
#5	-	0.5 F +.

Upper end of thread	Lower end of thread	Difference	δ	Upper end	Lower end	Difference	δ	Upper end	Lower end	Difference	δ
105°	99.62	5.38	−0.02	70.01	64.74	5.27	−0.13	35.08	29.66	5.42	±0.02
100.00	94.60	5.43	+0.03	65.00	59.60	5.40	±0.0	29.90	24.54	5.36	−0.04
95.02	88.62	5.40	±0.	59.92	54.52	5.40	±0.0	25.05	19.60	5.45	+0.05
90.00	84.61	5.39	−0.01	54.98	49.60	5.38	−0.2	19.89	14.42	5.47	+0.07
84.93	79.48	5.45	+0.05	49.93	44.50	5.43	+0.03	14.90	9.50	5.40	±0.0
80.05	74.61	5.44	+0.04	45.01	39.61	5.40	±0.0	10.10	4.69	5.41	+0.01
74.96	69.59	5.37	−0.03	40.00	34.60	5.40	±0.0	4.73	−0.65	5.38	−0.02
			+0.16				−0.12				+0.09

Calibrated as above with a thread about 5.4 divs: long and using a slip of mirror behind thermometer to avoid parallax.

On the 10th Apr: 1890, the boiling point was found to be at 99.4° (corrected). and on the 3rd March, the zero was found to be 0.2.

From these data we have the following results tabulated for reference

Thermometer Reading.	Correction additive to reading.
0	−0.2
5	−0.14
10	−0.11
15	−0.06
20	−0.09
25	−0.10
30	−0.02
35	+0.01
40	+0.05
45	+0.09
50	+0.11
55	+0.17
60	+0.21
65	+0.25
70	+0.43
75	+0.50
80	+0.50
85	+0.50
90	+0.55
95	+0.59
100	+0.59

Meter Test.

Measurement of the resistance of the new bottle.

The test detailed on page 124 was recommenced at 8.7 VI 89. The solution was made on this occasion very slightly acid (a drop) and the temperature was maintained by thermostat. In the hot box it was 32·2°C (90°F) and in the refrigerator 45°F (7·2°C). Owing however to the failure on some days to keep the temperature at this low point the average temp: in the refrigerator may be estimated at (46°F)-(7·7°C). The current was maintained for four hours daily at 8 milliampères to represent as fairly as possible practical working conditions on full load. The total number of hours work was by account 41.

The plates were set in the bottle on the 8th June to that they were immersed 15 days.

No. of plate	Weight of empty 4. VI. 89	Gain Sample weight 4. VI. 89	Sum.	Weight empty 19. VI. 89	Observed Sample weight 19. VI. 89	Sum.	Sample gain	Mean plate gain	Plate gain	Plate loss.
1	54·4635	109·156	109·156	54·5716	109·1600	109·1616	0·0056	0·003	0·4366	0·4310
2	54·7321			54·2900						
3	55·2341	108·385	108·385	55·6637	108·3896	108·3898	0·0038	0·002	0·4297	0·4249
4	53·1511			52·7261						
5	52·6931	106·868	106·868	52·9000	106·871	106·8717	0·0037	0·002	0·2580	0·2543
6	54·1756			53·9717						
7	49·6758	104·109	104·105	49·4200	104·1154	104·1150	0·0070	0·004	0·2650	0·2580
8	54·4420			54·6950						
9	54·0795	110·912	110·912	55·9535	110·9196	110·9199	0·0079	0·004	0·2494	0·2415
10	56·8171			55·0664						
11	35·0355	88·7104	88·710	35·0050	81·7110	81·7109	0·0009	0·000	0·0209	0·0200
12	53·6755			53·7059						
13	54·9351	109·738	109·737	54·8300	109·7416	109·7410	0·0040	0·002	0·1250	0·1210
14	54·7965			54·9110						
15	52·3551	106·901	106·902	52·7350	106·9060	106·9072	0·0052	0·003	0·1282	0·1230
16	54·0544			54·1722						
								Mean		

No. of plate	Mean of gain 1 to 8	Accepted Total deposit gr	Res: of shunt observed	W-w	W-w / w	Res: of bottle	Mean Res: of bottle	Mean temp.	Diff res: per °C.
1 2	0·4338	0·4338							
3 4	0·4273								3·605w / 24·5 = 0·11472w
5 6	0·2562		2·07	0·1776	0·6932	1·4235	1·463	32·2°C 90°F	for 15·5°C 1·463 + 147 × 0·1472 = 1·463 + 2·187 = 3·92w
7 8	0·2615		2·07	0·1723	0·6589	1·3644			
9 10	0·2455		2·075	0·1883	0·7670	1·591			
11 12	0·0205		2·01	0 —	•				for 20°C. 1·463 + 12·32 × 0·1472 = 1·463 + 1·785 = 3·248w
13 14	0·1230		2·03	0·3108	2·527	5·120	5·068	7·7°C 46°F	
15 16	0·1256		2·02	0·3082	2·454	5·006			

Mr R. S. White in a letter of 11th June from Paterson N.J. gave the following results for normal temp. (say 20°C) by the same method.

#2 plate (same as our) japanned. solution sent from here neutral 1·110

	Res: No 1 pair	No 2 pair	No 3 pair
First trial 21 hour continuous run.	2·95	3·50	2·64
Second - 47 - - -	2·26	3·93	2·23

Mean of all 2·92w

- all but #2 pair 2·52w

Carrying Capacity of Conductors.

June 19th Thursday.

Wires tested #6 covered (white) copper wire from Bergmann & Co. 0·202" = 0·513
covered to 0·300 = 0·762
Schenectady 0·290" = 0·737

Res. of gal. #2 bare soft " " " 2120 cmils. cond. (assumed)

No. of Obs.	Time	Ammeter Rdg	Amperes	Potentio. Reading	Amperes K=5	Mean Potentio. Reading	Amperes	Res. in cct with #2	Total Res. for #2 cts.	Res. of wire	Res. in cct $\frac{R}{r}$	rise temp.
1	16.[illegible]					0·0766	12·66	1440	4160	0·002489	1·00	—
2	$\frac{\cdot 55}{20}$	1·9	20	0·12145	20·58	0·1251	20·68	1450	4170	0·002495	1·0022	0·57
3	$\frac{30}{20}$	5·0	35	0·22.14	36.60	0·2250	37.68	1475	4195	0·002509	1·0080	2·06
4	$\frac{35}{20}$	7.0	50	0·3182	52·59	0·3208	53·02	1510	4230	0·002531	1·0170	4·37
5	$\frac{40}{20}$	8.58	62	0·4186	67·70	0·4111	67·96	1560	4280	0·002560	1·0285	7·33
6	$\frac{50}{17.00}$	10·52	83	0·5635	93·20	0·5589	92·08	1670	4390	0·002626	1·0550	14·14
7	$\frac{55}{20}$	11·95	100	0·6600	109·1	0·6578	108·7	1780	4500	0·002692	1·0815	20·98
8	$\frac{60}{20}$	12·93	112·5	0·7522	124·3	0·7504	124·0	1870	4590	0·002746	1·1030	26·46
9	$\frac{70}{20}$	14·10	123	0·8749	144·6	0·8711	144·0	2055	4775	0·002857	1·148	38·04
10	$\frac{80}{20}$	14·78	140	0·9574	158·2	0·9577	158·3	2220	4940	0·002955	1·187	48·27
11	$\frac{90}{20}$	15·95	158	1·100	181·8	1·108	181·5	2435	5155	0·003084	1·239	61·44
12	$\frac{95}{18.00}$	16·90	176	1·220	207·7	1·235	207·1	2675	5195	0·003118	1·249	64·01

No. of Obs.	Res. in cct with #6 wire	Total res. in #6 cts.	Res. of wire	$\frac{R}{r}$	rise of temp.	Temp. of air.	°C. rise for #2 above air	°C. rise for #6 above air	res. of #2 @ 0°C	sp. cond.	res. of #6 @ 0°C	sp. cond.
1	6040	8760	0·005239			22°C.			0·002493	~~0·004825~~	0·004825	
2	6040	8760	0·005239	1·0		0·1	0·5			$\frac{2093 \times 4825}{613}$	$\frac{4825 \times 2.87}{613}$	
3	6160	8880	0·005312	1·014	3·60	0·2	1·04	3·4		= 1596	1627	
4	6285	9005	0·005386	1·028	7·20	0·3	1·1	6·9				
5	6485	9205	0·005506	1·051	13·11	0·4	6·9	12·7		98·5%	100·4%	100·4%
6	6985	9565	0·005720	1·092	23·65	0·5	13·6	23·2				
7	7090	9810	0·005868	1·120	30·85	0·6	20·4	30·3				
8	7650	10370	0·006203	1·184	47·30	0·7	25·8	46·6				
9	8300	11020	0·006590	1·258	66·33	0·8	37·2	65·5				
10	8900	11620	0·006950	1·327	84·07	0·9	47·2	83·2				
11	9980	12,600	0·007536	1·438	112·6	1·0	60·4	111·6				
12	10630	13350	0·007984	1·524	134·7	23·3	63·7	133·4				

L.R. Ammeter corrected for large discount in error

Carrying Capacity of Conductors.

June 21st Friday

Wires tested Black covered wire from Bergmann's drum 0.288" 0.7314 0.332 0.2778 approximately #22 B.W.G. covered to 0.363" 0.9220 0.393 0.9958 bared

No.	Time	L.R. Amm.	Amperes	Potentiometer Rdg.	Amperes	Mean Potentiometer Rdg.	Mean amperes	Res. in cct with small wire 2.720	Total res. in small wire cct.	Res. of small wire	$\frac{R}{r}$	Rise temp.
1	15.15				0.09240		0.09140	15.84	1650	4380	0.002610	
2	$\frac{30}{30}$	2.65	24	0.1500	24.80	0.1505	24.88	1655	4385	0.002613	1.001	0
3	$\frac{40}{40}$	5.72	40	0.2557	42.27	0.2536	41.93	1660	4390	0.002616	1.0022	0.5
4	$\frac{50}{50}$	7.7	57	0.3106	56.30	0.3122	56.56	1695	4425	0.002637	1.0105	2.7
5	$\frac{50}{16.00}$	9.6	74	0.4402	72.78	0.4401	72.76	1727	4457	0.002656	1.0175	4.5
6	$\frac{50}{10}$	10.75	85	0.5200	87.60	0.5298	87.58	1785	4515	0.002691	1.0310	8.0
7	$\frac{10}{20}$	12.1	101	0.6257	103.4	0.6252	103.3	1840	4575	0.002727	1.01150	11.67

No.	Res. in cct with large wire 2.720	Total res. in large wire cct	Res. of large wire	$\frac{R}{r}$	Rise of temp.	Temp. air	Rise of temp. in small wire	Rise of temp. in large wire	Res. of small wire at 0°C	% Conductivity	Res. of large wire at 0°C	% Cond.
1	710	3440	0.002054			25.5			18.69×10^{-3}	$\frac{1.46 \times 2.279}{613}$ 1620 resistivity	2.279×10^{-3}	
2	715	3445	0.002053	1.0015	0.2		0.0	0		107%	$\frac{2.279 \times 10^{-3} \times 1.62}{613}$ 1620 resistivity	
3	720	3450	0.002056	1.0032	0.8		0.5	0.5				100%
4	735	3465	0.002065	1.008	2.1		2.7	2.1				
5	755	3485	0.002077	1.0114	3.6		4.5	3.6				
6	782	3512	0.002093	1.021	5.4		8.0	5.4				
7	822	3552	0.002117	1.033	8.5		11.6	8.5				

The continuation of this test was prevented by the compound in the tube catching fire owing to a contact on putting a load in circuit with two small conductors.

June 24th Saturday

Carrying Capacity of Conductors.

(141)

Same wire as in the last interrupted test.

Black covered Benjamin's wire Diam. 0.288" taped to 0.343" No 2
0.7314 cm 0.8720 cm
0.322" leaded to 0.392
0.8178 " " 0.9958 No 1/2

No of obs.	Time	L.R. Ammeter Rdg.	Amperes	Potentio Rdg.	Amperes	Mean Potentio Rdg.	Mean Amperes	Res. in cut with 0.731	Total Res. in cut of 0.731 (2720)	Res. of 0.731	$\frac{A}{T}$	Rise of temp. °C
1	13.20	1.6	19	0.1229	20.31	0.1229	20.31	15.35	42.55	0.002539		
2	.35/50	E				0.1241	20.51	15.35	42.55			
3	.35/50	5.65	40	0.2502	41.36	0.2561	42.33	15.60	42.60	0.002528	1.0038	1°
4	.45/50	8.6	62	0.3912	64.66	0.3913	64.68	16.25	43.45	0.002559	1.0080	2.06
5	.50/14.00	10.4	81	0.5015	82.90	0.5020	83.00	16.95	44.15	0.002461	1.040	10.28
6	.50/75	11.42	92	0.5725	94.65	0.5698	94.20	17.60	44.80	0.002480	1.066	14.40
7	.50/30	13.65	123	0.7496	123.9	0.7493	123.8	18.85	46.05	0.002724	1.188	21.85
8	.35/30	15.0	142	0.8880	146.8	0.8882	146.8	20.25	47.45	0.002839	1.118	30.33
9	.35/40	16.16	163	1.0024	165.7	1.0050	166.1	22.15	49.35	0.003022	1.163	41.91
10	.50/50	17.25	186	1.1328	187.5	1.1290	186.6	23.02	51.02	0.003052	1.202	51.93
11	.50/16.00	18.75	218	1.2330	203.8	1.2352	204.1	25.75	52.95	0.003168	1.248	63.75
12	.50/50	19.57	232	1.3596	224.7	1.3482	222.9	28.00	55.20	0.003302	1.301	77.38
13	.35/35	20.40	251	1.4484	239.5	1.4458	241.0	30.30	57.50	0.003440	1.355	91.26
14	.35/65	21.4	275	1.6072	265.6	1.5935	263.7	33.30	60.50	0.003619	1.426	119.5

No. of Obs.	Res. in cut with 0.818	Total Res. in cut of 0.818 (2720)	Res. of 0.818	$\frac{A}{T}$	Rise of temp. °C	Temp. air °C	Rise of temp. cut 0.731	Rise of temp. cut 0.818	Res. of 0.731 @0°C	Conductivity %	Res. of 0.818 @0°C	Conductivity %
1	675	3395	0.002031			24.5°			0.002318		0.001852	
2	675	3395					1.0	1.50				1162.5/613
3	695	3415	0.002043	1.006	1.54					1588		1589
4	720	3440	0.002044	1.006	4.11		2.0	4.0				Mistake
5	755	3475	0.002079	1.024	6.17	.2	10.1	6.0				
6	795	3515	0.002103	1.036	9.26	.2	14.1	9.0		102.4%		102.4%
7	850	3570	0.002136	1.052	13.37	.4	21.5	13.0				
8	932	3652	0.002185	1.076	19.52	.5	29.9	19.0				
9	1027	3747	0.002242	1.104	26.74	.6	41.3	26.1				
10	1135	3855	0.002306	1.135	34.7	.7	51.2	34.0				
11	1247	3967	0.002373	1.169	43.44	.8	63.0	42.6				
12	1415	4135	0.002473	1.218	58.05	.9	76.5	55.2				
13	1545	4265	0.002552	1.257	66.06	1.0	90.3	66.0				
14	1745	4465	0.002671	1.315	81.00	25.5	109.5	80.0				

Res. of gauge 2720 ω each coil

Carrying Power of Conductors.

June 24th Monday
Wires tested as follow.
From Bergmann & Co Black covered wire diam 0.328" (0.825) covered (to pole) 0.425" 1.079
White - - - 0.340" (0.863) . braided . 0.466" 1.183

Res of yellow 2730 each coil

No.	Time	L.R. Ammeter	Amperes	Potentio Rdg.	Amperes	Mean Potentio Rdg.	Mean Amperes	Res in coil with 0.825 1.0714	Total Res in 1.079 coil	Res of 1.0714 0.825	R/T	Rise of temp
1	10.20	4.6	34	0.2060	34.05			620	3350	0.001997		
2	24/30			0.		0.2066	34.44	635	3365	0.002016	1.003	0.79
3	38/40	7.75	55	0.3394	56.10	0.3394	56.10	652	3382	0.002036	1.008	2.06
4	45/50	10.55	84	0.5002	82.66	0.4990	82.46	683	3413	0.002035	1.0775	4.50
5	55/60	12.8	110	0.6566	108.5	0.6578	108.7	735	3465	0.002066	1.0320	8.48
6	1.10/10	14.5	135	0.8055	133.1	0.8128	134.3	800	3530	0.002106	1.0580	13.37
7	15/20	16.5	168	0.9950	164.44	0.9936	164.2	914	3644	0.002172	1.0886	22.11
8	24/30	17.6	190	1.1200	185.1	1.1180	184.9	997	3727	0.002222	1.111	28.53
9	35/40	19.35	227	1.3528	223.6	1.3476	222.7	1175	3905	0.002328	1.164	42.16
10	45/50	21.1	267	1.5252	252.0	1.5818	257.5	1365	4095	0.002441	1.221	56.81
11	55/1.00	22.0	291	1.6590	274.2	1.6460	272.0	1570	4300	0.002563	1.282	72.50
								1620	4350	0.002593	1.297	76.34

No.	Res in coil with 0.863	Total res in 0.863 coil 2730	Res of 0.863	R/T	Rise of temp. °C	Temp air	Rise of temp coil 0.825	Rise of temp coil 0.863	Res of 0.825 @ 0°C	Conductivity γ	Res of 0.863 @ 0°C	Conductivity γ
1	395	3125	0.001863						0.001820		0.001716	
2	405	3135	0.001869	1.003	0.79	22°C	0.7	0.7		1210.58296 / 613		1266.55964 / 613
3	417	3147	0.001876	1.007	1.90	"	2.0	1.7		1605 resistivity		1637 resistivity
4	445	3175	0.001892	1.016	4.11	"	4.3	6.9		100.95		99.0
5	483	3213	0.001915	1.028	7.20	"	8.2	6.9				
6	540	3270	0.001949	1.046	11.82	"	13.0	11.4				
7	635	3365	0.002006	1.078	20.05	"	21.6	19.6				
8	714	3444	0.002051	1.101	25.96	"	27.9	25.4				
9	847	3577	0.002132	1.1444	37.02	"	41.5	36.3				
10	1005	3735	0.002226	1.195	50.13	"	56.0	49.3				
11	1140	3870	0.002307	1.225	61.44	"	71.6	60.5				
	1190	3920	0.002336	1.254	65.28	23°C	75.3	64.3				

Carrying Power of Conductors.

24th June Monday

Wire tested as follows

From Bergmann & Co black covered wire drawn: 0.364" (0.9244) taped to 0.460" (1.168)

" " " " 0.4455" (1.131) braided 0.550" (1.397)

Res: of galvo coils 2730 each side

No Obs	Time	L.R. Ammeter	Amperes	Potentio Rdg.	Amperes	Mean Potentio Rdg.	Mean Amperes	Res: in cct with 0.9244	Total res in 0.9244 cct	Res: of 0.9244	A/T	Rise of temp
1	16.20	4.2	31	0.1908	31.54	—		19 ~~1.908~~ ~~0.1908~~	27.19	0.001638		
2	20/20	4.2	31	0.1909	31.54	0.1904	31.48					
3	30/30	5.8	55	0.3629	56.36	0.3396	56.110					
4	40/40	10.9	86	0.5020	83.00	0.5033	83.20					
5	50/15.00	12.9	112	0.6602	109.1	0.6574	108.6					
6	60/10	14.8	140	0.8088	132.2	0.8076	132.5					
7	70/20	16.6	171	0.9984	164.0	0.9946	164.14					
8	80/30	18.1	200	1.2580	207.9	1.2520	207.0					
9	90/40	20.8	260	1.4464	239.0	1.4459	239.0	350	3480	0.001935	1.120	30.01
10	100/50	22.8	285	1.5936	263.5	1.6152	267.0	475	3205	0.001910	1.166	42.68
11	110/60	22.6	306	1.7750	293.14	1.7616	291.2	590	3320	0.001979	1.208	52.48
12	120/70	23.1	320	1.8784	307.3	1.8314	302.7	709	3439	0.002050	1.252	64.79

No of Obs	Res: in cct with temp not the	Total res in 0.9244 cct.	Res: of 1.131	A/T	Rise of temp °C	Temp: of air	Res: of temp cct 0.9244	Res: of temp cct 1.131	Res: of 0.9244 @ 0°C	% Conductivity	Res: of 0.131 @ 0°C	% Cond.
1	1300	4020	0.001102			23°C.			0.001504	150 x 4020 / 613	0.001112	100 x temp / 60
2	1300	4030	0.001102			81						
3	1297	4027	0.001103	1.001	0	82		5		164.3		165.6
4	1285	4015	0.001106	1.005	1.25	0.5	0	0.4				
5	1265	3995	0.001112	1.011	2.83	0.7		2.1		96.6%		97.0
6	1235	3965	0.001120	1.018	4.63	0.9		3.7				
7	1192	3927	0.001131	1.028	7.20	1.1		6.1				
8	1122	3852	0.001153	1.048	12.30	1.3		11.0				
9	1027	3757	0.001182	1.074	19.02	1.5	29.3	17.5				
10	955	3685	0.001205	1.095	24.42	1.7	41.	22.7				
11	852	3582	0.001240	1.127	32.65	1.9	51.7	30.9				
12	780	3510	0.001266	1.151	39.8	1.9	62.9	36.9				
						25°C						

Meter Test.

Took a test to obtain the res. of the meter bottle at ordinary temperatures. Six couples were weighed and set up on the 21st June. The current was started at 3 ampe. at noon and continued for 92 hours until 8 o'clock 25th June. The mean temp during the interval was about 75°.5 or 24°.C. The solution was similar to that used in the last test and was very slightly acid (4 drps) Four bottles were shunted by two shunt coils

No. of Couple	Weight 21.VI.89	Sum	Joint wt Ark	Weight 25.VI.89	Sum	Joint WG Ark	Loss.	Gain	Mean	Couple gain	Plate gain
1 2	53·5189 54·7878	108·2767	107·2765	53·8203 54·4584	108·2787	108·2850	0·3424	0·3514	0·3469	0·0090	0·0015
3 4	51·5990 52·3129	103·9123	103·9110	51·9492 51·9650	103·9142	103·9136	0·3479	0·3498	0·3441	0·0019	0·001
5 6	52·3557 53·7582	106·1111	106·1100	52·3943 53·7206	106·1149	106·1142	0·0344	0·0384	0·0365	0·0038	0·002
7 8	54·9390 54·2165	109·1555	109·1555	54·9120 54·2493	109·1613	109·1607	0·0270	0·0328	0·0299	0·0058	0·003
9 20	55·6303 54·5510	110·1813	110·1810	55·6964 54·5766	109·1821	110·1830	0·0242	0·0250	0·0246	0·0017	0·001
13 14	54·4444 57·7495	112·1639	112·1632	54·4376 57·7423	109·1677	109·1674	0·0193	0·0231	0·0212	0·0038	0·002
										Mean	0·002

No. of Couple	Shunted by.	Resistance W	W − w	$\frac{W-w}{w}$
1 2	∞	0·31455		
3 4	∞			
5 6	2·07		0·2090	8·147
7 8	2·07		0·3156	10·52
9 20	2·07		0·3209	13·05
13 14	2·07		0·3243	15·30

From some cause not known, the results seem hopelessly wrong.

t	C°	Res: per cm.	Energy per cm.	$(1.0077)^t \times 0.05825$	$(1.0077^t - 1)$	Energy indicated per cm.	Energy converted
1	432.7	3.949×10^{-5}	1.709×10^{-2}				
7.5	1681	4.946×10^{-5}	6.800×10^{-2}		0.0445		
23.4	3468	4.290	1.488×10^{-1}		0.0135		
37.5	5358	4.590	2.440		0.0233		
61.2	7815	4.894	3.825		0.0417		
91.5	11300	5.236	5.824		0.0710		
114.7	13450	5.692	7.657		0.0980		
156.3	17680	6.324	1.118				
	22.940	6.324	1.451				

Carrying Capacity of Conductors.

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A pair of posts 180 cms high were set about 620 cms apart just outside and in a line parallel to the galvanometer building. These carried each a cross arm at the top 300 cms long with five insulators in them at 30 cms distances apart. Nine wires were stretched parallel from between these cross arms from opposite insulators. These wires were as follows counting from outside in i.e. the building.

			Length cms	Drains: in cms	Drains: in cms	Condition	Area: sq. inch	Area: cm.	Sq. cms	Page
3/0 #2	No. 1		607	0.296	0.737	bare soft Schitz	0.0861	80,100	0.14266	139
#4	- 2		608	0.239	0.607	- - -	0.0249	57,100	0.2894	136
	- 3 -		610	0.203	0.516	- - -	0.0324	44,200	0.2091	136
#6	- 4	(1)	615	0.135	0.343	white cotton and by (0.163 / 0.152)	0.1143	17,230	0.0924	—
#10 - #8 -	- 5 -		617.5	0.163	0.414	black cotton to (0.328 / 0.324)	0.0209	26,600	0.1346	—
#12	- 6 -	(1)	615	0.110	0.279	bare soft Schitz	0.0095	12,100	0.0611	—
#10	- 7 -	(2)	617.5	0.1365	0.3416	- - -	0.0142	18,200	0.0960	133
#8	- 8	(2)	616	0.164	0.417	- - -	0.0211	26,900	0.1366	133
#6	- 9		613	0.202	0.513	white cotton to (0.302 / 0.297)	0.0320	40,600	0.2057	139

Cables were led out to these wires and the current led up and down. The P.D. was taken off by insulated wires attached close up to the insulators and led through the windows. The wires tested on the first day were #~~4~~ 6 7 + 8 that is #~~8~~10 8, 10, + 12. B.W.G. June 27th Thursday. The same connections as usual were employed, and the grating in multiple as the standard res: of 0.0121 ω. Res: of galv at start 2710 ω per coil

No. Obs.	Time.	C.R. Ammeter	Amperes	Potentio Rdg. 16.23	Amperes	Mean Potentio Rdg.	Mean Amperes	Res: in ct with #4	Total res in #4 ct	Res of #4	Temp	Rise Temp C°
				0.024	3.98	0.0241	3.98	2710	5420	0.0242	1.00	
1	15.20/20	1.90	20	0.1245	20.58	0.1260	20.83	2730	5460	0.02429	1.000	1.
2	.40/20	5.65	40	0.2470	40.82	0.2480	40.99	2764	5574	0.02489	1.029	7.5
3	.60/20	8.0	57	0.3516	58.12	0.3561	58.86	3200	5910	0.02639	1.091	23.4
4	16.00/80											
5	.00/73	9.5	72	0.4406	72.82	0.4427	73.17	3500	6210	0.02773	1.146	37.5
6	.55/22	11.0	87	0.5304	87.66	0.5347	88.38	4000	6710	0.02996	1.238	61.2
7	.33/32	12.5	107	0.6430	106.3	0.6420	106.3	4640	7350	0.03282	1.356	91.5
8	.18/20	13.3	117	0.6989	115.5	0.7097	115.8	5120	7840	0.03501	1.446	114.7
9	.40/80	15.0	143	0.8100	133.9	0.8031	132.7	6000	8710	0.03890	1.605	156.3
10	.32/17.00	15.6	153	0.8945	147.8	0.9161	151.4	-	-	-		
11	.22/15	16.2	164	1.0000	165.3	0.9838	162.6	-	-	-		
12	.55/36	17.4	186	1.0972	181.3	1.0972	181.3	-	-	-		

The day was sultry and cloudy with very little wind. The temp: was 28.2° in the shade dry bulb + 26.1° wet bulb. The readings were very unsteady and seemed to be affected by slight movement in the air

E	C^2	C. Arm 0.7761 Res: per cm.	Energy per cm.	Emissivity per sq. cm. Kaufmann	(1.0077^8) $\times 0.0625$	$(1.0077^t - 1)$	Energy radiated per linear cm.	Energy conducted per linear cm.
5.4	1681	2.913×10^{-5}	4.896×10^{-3}	0.02896		0.003	0.0026	0.02664
15.9	3469	3.030	1.051×10^{-1}	0.1051		0.0093	0.0082	0.0969
25.0	5358	3.133	1.679	0.1679		0.015	0.0132	0.1547
39.1	7815	3.285	2.646	0.2646		0.02442	0.0212	0.2434
59.9	11300	3.519	3.977	0.3977		0.02424	0.0354	0.3623
80.5	13400	3.745	5.018	0.5018		0.060	0.0526	0.4492
110.5	17600	4.080	7.18×10^{-1}	0.7180		0.093	0.0815	0.6265
		0.9465						
3.3	1681	2.006×10^{-5}	3.373×10^{-3}	0.03337		0.0023	0.0025	0.0312
13.1	3469	2.08	7.216	0.07222		0.0076	0.0082	0.0640
17.9	5358	2.18	1.135×10^{-1}	0.11135		0.0104	0.0112	0.1023
31.6	7815	2.223	1.738	0.1738		0.0191	0.0205	0.1533
47.0	11300	2.343	2.647	0.2647		0.0304	0.0326	0.2324
56.8	13400	2.414	3.234	0.3234		0.0386	0.0414	0.2820
90.2	17600	2.674	4.706	0.4706		0.070	0.0751	0.3955
2.3	1681	1.395×10^{-5}	2.218×10^{-3}	0.0222		0.001	0.0013	0.0209
7.5	3469	1.346	4.67	0.0467		0.00444	0.0058	0.0409
9.5	5358	1.356	7.266	0.0727		0.0055	0.0072	0.0655
19.5	7815	1.407	1.099×10^{-1}	0.1099		0.0112	0.0147	0.0952
26.5	11300	1.442	1.630	0.1630		0.0158	0.0207	0.1423
32.7	13400	1.473	1.975	0.1975		0.020	0.0259	0.1716
49.9	17600	1.561	2.747	0.2747		0.033	0.0432	0.2315
79.5	22940	1.712	3.927	0.3927		0.059	0.0773	0.3154
83.0	26400	1.729	4.564	0.4564		0.0625	0.0819	0.3745
107.2	32800	1.853	6.077	0.6077		0.0892	0.1169	0.4908

Carrying Power of Conductors.

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No. of Obs.	No. of wire	Diam: cms.	Res: in cct. with wire	Total res. in wire cct. 27°.0	Res: of wire	$\frac{R}{r}$	Rise of temp. above air	Rise of wire 100°	Absolute Conductivity	Cond: %	Amperes
1	6 #12	0.279	1220	3930	0.01755	1.00	0.26	0.01582	0.0152 $\frac{5.0641}{615.1572}$	97.0%	4
2			1225	3935	0.01757	1.001	0.26				20.8
3			1303	4013	0.01792	1.021	#54				41
4			1465	4175	0.01864	1.062	11.59				58.9
5			1605	4315	0.01927	1.098	21.50				73.2
6			1815	4525	0.02021	1.152	31.91				88.4
7			2135	4845	0.02164	1.233	51.99				106.3
8			2450	5160	0.02304	1.313	80.05				115.8
9			2910	5620	0.02509	1.430	110.5				132.7
10			3295	6005	0.02681	1.528	135.7				151.4
11			3700	6410	0.02862	1.631	162.2				162.6
12	–		4685	7395	0.03302	1.882	226.7				181.3
13											

No. of Obs.	No. of wire	Diam: cms.	Res: in cct. with wire	Total res. in wire cct.	Res: of wire	$\frac{R}{r}$	Rise of temp.	Amperes	Rise of wire 100°	conductivity	% Conductivity
1	7 #10	0.3416	30	2740	0.01223	1.00		4	0.01103	$\frac{1103 \times 0.0625}{617.5}$ $= .1786$	100.5%
2		0.073	35	2745	0.01226	1.0025	0.6	20.8			
3			64	2774	0.01239	1.013	3.34	41			
4			167	2877	0.01285	1.051	13.11	58.9			
5			220	2930	0.01308	1.0695	17.87	73.2			
6			365	3075	0.01373	1.123	31.62	88.4			
7			530	3240	0.01447	1.183	47.04	106.3			
8			635	3345	0.01494	1.221	56.81	115.8			
9			990	3700	0.01652	1.351	90.22	132.7			
10			1695	4305	0.01922	1.5722	147.1	151.4			
11			–								
12			–								

No. of Obs.	No. of wire	Diam cms.	Res: in cct. with plating 27°.0	Total res. in plating cct. 27°.0	Res: of wire	$\frac{R}{r}$	Rise of temp.	Amperes	Rise of wire 100°	conductivity	% conductivity
1	8 #8	0.417 0.310	1350	4070	0.008058	1.00		4	0.007268	$\frac{72268 \times 0.0625}{616.}$ $= 1.612$	100
2			1360	4070	0.008058	1.00		20.8			98.99
3			1325	4035	0.008128	1.009	2.3	41.			99%
4			1245	3955	0.007292	1.029	7.6	58.9			
5			1215	3925	0.008354	1.037	9.5	73.2			
6			1072	3782	0.007670	1.076	19.5	88.4			
7			980	3690	0.007886	1.103	26.5	106.3			
8			902	3612	0.007079	1.127	32.7	115.8			
9			700	3410	0.007618	1.194	49.9	132.7			
10			400	3110	0.01055	1.309	79.5	151.4			
11			367	3077	0.01066	1.323	83.0	162.6			
12			160	2870	0.01142	1.417	107.2	181.3			

Day Fine, but wires in shade. –

Res. of galv. at commencement 54.555 ω T.B. 24.8°C } 27.30 ω per unit
– close 54.20 ω 27.5°C

Temperature – commencement Dry 29° wet 24.4° galv. room 25°
– close 27.2 . 24.4 . 25°

Photographs taken of wires and poles

Readings unreliably from occasional gusts of wind, but day was fairly calm.

Circumference (mm)	Potential Temp	Current	C°	Res. per cm.	Energy per cm.	Radiation	Total radiation	Convection
2.315								
	5.9	155.4	24.150	4.274×10^{-4}	1.032×10^{-2}	0.003	0.0069	0.0063
	7.1	175.7	30.800	4.308	1.327	0.004	0.0093	0.0234
	12.3	202.3	40.900	4.395	1.798	0.007	0.0162	0.0136
	16.1	222.7	49.800	4.455	2.286	0.0095	0.0220	0.0186
	17.2	242.9	59.000	4.473	2.600	0.010	0.0232	0.0208
	23.1	268.5	72.000	4.571	3.292	0.0136	0.0315	0.0277
	41.1	292.5	85.500	4.863	4.161	0.0262	0.0607	0.3552
	46.8	300.1	90.000	4.955	4.460	0.0310	0.0718	0.3742
1.906	5.11	72.6	5271	6.376×10^{-4}	3.361×10^{-2}	0.003	0.00572	0.0279
	6.4	92.7	8593	6.406	5.504	0.0039	0.007743	0.0476
	7.5	114.4	13100	6.433	8.437	0.00444	0.00839	0.0759
	9.5	133.5	17800	6.483	1.154×10^{-1}	0.0055	0.010747	0.1049
	12.7	155.4	24150	6.552	1.585	0.007	0.013344	0.1452
	17.7	175.7	30870	6.675	2.061	0.003	0.01963	0.1865
	24.7	202.3	40900	6.902	2.823	0.016	0.030749	0.2518
	36.8	222.7	49500	7.148	3.538	0.023	0.043893	0.310
	37.5	242.9	59.000	7.166	4.228	0.0235	0.044478	0.378
	47.3	268.5	72.000	7.404	5.331	0.031	0.059054	0.474
	44.5	292.5	85500	7.334	6.272	0.029	0.05546	0.568
	52.4	300.1	90.000	7.524	6.771	0.035	0.06670	0.670
1.621	3.1	53.9	2905	8.762×10^{-4}	2.545×10^{-2}	0.002	0.0032	0.0223
	5.2	72.6	5271	8.936	4.710	0.0047	0.007612	0.0395
	9.3	92.7	8593	8.974	7.72	0.0051	0.008277	0.0688
	13.2	114.4	13100	9.102	1.192×10^{-1}	0.0075	0.01216	0.1070
	16.7	133.5	17800	9.226	1.642	0.0096	0.015576	0.1456
	23.7	155.4	24150	9.452	2.293	0.014	0.0227	0.2056
	31.9	175.7	30870	9.730	3.004	0.0196	0.0318	0.2686
	48.0	202.3	40.900	1.028×10^{-1}	4.313	0.031	0.0503	0.3840
	58.1	222.7	49.500	1.062	5.257	0.039	0.0632	0.4625
	67.6	242.9	59.000	1.094	6.454	0.0485	0.0778	0.5676
	84.6	268.5	72.000	1.151	8.288	0.064	0.1038	0.725
	164.8							
	185.9							

June 29th Friday

Carrying Power of Conductors.

(47)

No. of Obs.	Time	C.R. Ammeter	Amperes	Potentio Rdg	Amperes	(1.1) Mean Potentio Rdg	Mean amperes	Res. in cut with grating	Total res in grating cut	Res. of 1 unit	R/r	Rise temp.
1	11h 40					0.07145	12.31	10.320?				
2	50/15	4.0	29	0.1900	31.41	0.1899	31.39	10.245	12.975	0.002286		
3	55/15	7.4	53	0.3232	51.77	0.3258	53.85	10.175	12.905	0.002260	1.005	1.29
4	45/16	9.4	71	0.4400	72.73	0.4389	72.55	10.020	12.750	0.002291	1.018	1.46
5	25/25	11.5	94	0.5600	92.56	0.5611	92.74	10.050	12.780	0.002288	1.015	1.86
6	55/25	13.2	116	0.6925	114.5	0.6924	114.4	9.970	12.700	0.002560	1.022	5.66
7	25/16.10	14.6	136	0.8065	133.3	0.8078	133.5	10.060	12.790	0.002553	1.013	3.36
8	10/35	15.9	158	0.9425	155.4	0.9403	155.4	10.000	12.720	0.002595	1.0195	5.01
9	35/35	17.1	180	1.0600	175.2	1.0620	175.7	9.900	12.630	0.002615	1.0275	7.47
10	50/35	18.6	210	1.2020	198.7	1.2240	202.3	9.650	12.380	0.002688	1.056	12.34
11	20/17.10	19.5	230	1.3534	223.7	1.3476	222.7	9.480	12.210	0.002745	1.0587	16.12
12	35/25	20.1	244	1.4348	237.1	1.4496	242.9	9.420	12.160	0.002716	1.067	17.21
13	55/25	21.5	277	1.6260	268.7	1.6244	268.5	9.170	11.900	0.002776	1.090	23.46
14	15/27	22.7	310	1.7750	293.4	1.7694	292.5	8.860	11.590	0.002953	1.160	40.3
15	45/18.00	22.9	315	1.8216	301.2	1.8150	300.1	8.250	10.980	0.003008	1.182	46.98

$R_{20°C}$ of 0.002 $\frac{0.002 \times 0.0246}{0.07}$ = 1.411

79%

No. of Obs.	No. of wires	Diam. mm.	Res. in cut with grating	Total res in grating cut	Res. of wire	R/r	Rise of temp.	Amperes	Res. of wire @ 0°C	Conductivity	% Cond.
1	2	0.607	10.320								
2			5760	8690	0.003801	1.0			0.003828	$\frac{4.828 \times 2.54}{0.07}$	100.7
3			5905	8635	0.003826	1.0060	1.56	53.5		1632	
4			5790	8520	0.003877	1.020	5.14	72.6			
5			5750	8480	0.003895	1.025	6.43	92.7			
6			5715	8445	0.003911	1.029	7.45	114.4			
7			5650	8380	0.003942	1.037	9.51	133.5			
8			5550	8280	0.003989	1.0495	12.73	155.4			
9			5440	8140	0.004059	1.0690	17.74	175.7			
10			5140	7870	0.004197	1.1040	26.74	202.3			
11			4870	7600	0.004347	1.143	36.77	222.7			
12			4850	7580	0.004357	1.146	37.53	242.9			
13			4610	7340	0.004501	1.184	47.20	268.5			
14			3680	6410	0.004959	1.173	44.47	292.5			
15			3490	6220	0.004575	1.204	52.44	300.1			

No. of Obs.	No. of wires	Diam. mm.	Res. in cut with grating	Total res in grating cut	Res. of wire	R/r	Rise of temp.	Amperes	Res. of wire @ 0°C	Conductivity	% Cond.
1	3	0.516	3480?	6210?							
2			3325	6255	0.005282	1.			0.004763	$\frac{4.763 \times 2.54}{0.07}$	100.7
3			3250	6180	0.005315	1.012	3.08	53.9		1632	
4			3230	6060	0.005451	1.032	8.23	72.6			
5			3225	6035	0.005474	1.036	9.25	92.7			
6			3220	5950	0.005553	1.0515	13.24	114.4			
7			3240	5870	0.005627	1.065	16.91	133.5			
8			3090	5730	0.005766	1.092	23.65	155.4			
9			2884	5584	0.005936	1.124	31.97	175.7			
10			2540	5270	0.006268	1.1865	47.95	202.3			
11			2370	5100	0.006477	1.226	58.10	222.7			
12			2220	4950	0.006672	1.263	67.61	242.9			
13			1975	4705	0.007020	1.329	84.60	268.5			
14			1080	3810	0.008670	1.6411	164.18	292.5			
15			900	3630	0.009102	1.723	185.9	300.1			

Wire	Temp: elevation	C	C^2	Rec. per cm	Energy per cm	Radiation per sq cm	Total radiation per cm	Energy per cm	Convection
1.310	4.9	53.8	2905	1.329×10^{-4}	3.862×10^{-2}	0.003	0.0039	0.0386	0.0347
	14.14	72.6	5271	1.376	7.254	0.008	0.0705	0.0725	0.0620
	18.0	92.7	8593	1.395	1.199×10^{-1}	0.0105	0.0738	0.1199	0.1061
	28.3	114.4	13100	1.447	1.896	0.0155	0.0203	0.1896	0.1693
	41.9	133.5	17800	1.517	2.700	0.027	0.0354	0.2700	0.2366
	58.4	155.4	24150	1.601	3.867	0.0383	0.0502	0.3867	0.3365
	93.1	175.7	30870	1.776	5.482	0.073	0.0956	0.5482	0.4526

Carrying Power of Conductors.

No. of Obs	W	No. of wires	Diam. Diameter	Rec. Current with Heating	Rec. Current Rec. Current Square	Resistance Rec. per cm wire	R_t / T	Rise of temp	Amperes	Rec. of wire & o/o	Conductivity	f Conductivity
1	5	89	0.4144	1225?						0.007448	760×144 / 415	
2				1275	4005	0.008269						
3				1220	3950	0.008362	1.0114	3.60	53.8		1622	100.1
4				1100	3830	0.008625	1.0455	11.87	72.6			
5				1057	3787	0.008724	1.0575	14.78	92.7			
6				917	3647	0.009060	1.098	25.20	114.4			
7				802	3532	0.009362	1.138	34.31	133.5			
8				680	3410	0.009696	1.174	44.72	155.4			
9				465	3195	0.010334	1.253	65.04	175.7			
10				165	2895	0.011141	1.383	98.46	202.3			
11												
12												
13												
14												
15												

Short circuited

No. of Obs	W	No. of wires	Diam. Diameter	Rec. Current with Heating	Rec. Current Rec. Current Square	Resistance Rec. per cm wire	R_t / T	Rise of temp	Amperes	Rec. of wire & o/o	Conductivity	f Conductivity
1	8	89	0.417	1380	4090	0.008036				0.007248	724×144 / 414	
2				1360	4070	0.008075	1.045	1.29	31.4			
3				1305	4035	0.008180	1.079	4.89	53.8		1608	99.28
4				1165	3895	0.008480	1.055	14.14	72.6			
5				1112	3842	0.008597	1.070	18.0	92.7			
6				975	3705	0.008916	1.110	28.28	114.4			
7				805	3535	0.009363	1.163	41.9	133.5			
8				620	3350	0.009860	1.227	58.36	155.4			
9				290	3020	0.010940	1.362	93.06	175.7			
10				−100	2630	0.012560	1.561	144.2	202.3			
11												
12												
13												
14												
15												

Short circuited

No. of Obs	W	No. of wires	Diam. Diameter	Rec. Current with Heating	Rec. Current Rec. Current Square	Resistance Rec. per cm wire	R_t / T	Rise of temp	Amperes	Rec. of wire & o/o	Conductivity	f Conductivity
1	9	86	0.513	3400	6130	0.005389				0.004860	1460×267 / 613	
2				3387	6117	0.005406	1.002	0.5	31.4			
3				3355	6085	0.005458	1.007	1.8	53.8		1639	101.2
4				3245	5975	0.005639	1.026	6.68	72.6			
5				3200	5930	0.005709	1.033	8.48	92.7			
6				3110	5840	0.005856	1.0495	12.72	114.4			
7				3002	5732	0.005763	1.069	17.74	133.5			
8				2872	5602	0.005996	1.094	24.17	155.4			
9				2670	5400	0.006417	1.135	34.70	175.7			
10				2420	5160	0.006902	1.188	48.33	202.3			
11				2250	4980	0.006632	1.2305	59.26	227.7			
12				2092	4782	0.006990	1.295	75.84	242.9			
13				1940	4520	0.007367	1.356	91.52	268.5			
14				1745	4075	0.008196	1.504	129.6	292.5			
15				1120	3860	0.008660	1.588	151.2	304.1			

Meter Test.

The last test having given such anomalous results was repeated, under the same conditions. It commenced at 16.25.VI and ended at 9.29.VI., the current being maintained as before at 3 milliamperes. About 8½ hours in all. As in the previous case the bottle that took the whole current smutted. The mean temp. was about 24°C. Couple 3–4 was swapped to clean, all the varnish being removed.

No. of Bot.	Shunt	Weight 25th VI.	Observed empty weight	Sum.	Weight 29th VI.	Sum.	Loss	Gain	Mean Loss or gain	Gain per couple	Gain per bottle
1 / 2	∞	53.5895 / 54.0586	107.6483	107.6481	53.8654 / 53.7900	107.6554	0.2686	0.2759	0.2723	0.0073	0.004
3 / 4	2.06	51.5087 / 51.6790	103.1870	103.1877	51.6420 / 51.5508	103.1928	0.1282	0.1333	0.1308	0.0051	0.003
5 / 6	∞	52.2458 / 53.5990	105.8442	105.8448	52.5158 / 53.3360	105.8518	0.2630	0.2702	0.2666?	0.0072	0.004
7 / 8	2.06	54.7676 / 54.0791	108.8462	108.8467	54.8651 / 53.9850	108.8501	0.0941	0.0975	0.0958	0.0034	0.002
9 / 10	2.06	55.5043 / 54.4887	109.9930	109.9920	55.6018 / 54.3962	109.9980	0.0925	0.0975	0.0950	0.0050	0.003
11 / 12	~~2.06~~	54.4827 / 54.6023	109.0850	109.0835	54.4950 / 54.5362	109.0312	0.0726	0.0763	0.0745	0.0077	0.004
13 / 14	~~2.06~~										
											Mean 0.003

No. of Bot.	Average fill obs.	W − w	(W − w)/w	Rev. of bottle
1 / 2	0.2723			
3 / 4		0.1415	1.08	2.225
5 / 6		—		
7 / 8		0.1765	1.814	3.751
9 / 10		0.1779	1.82	3.75
11 / 12		0.1978	2.636	5.47

Observation on the Accuracy of the Barometer Scale.

June 29th Saturday

Mercury in reservoir of barometer cleaned. After the operation the distance between point and scale reading was observed by cathetometer as follows.

With one telescope only.

Reading of point 38.674
68 cm mark 106.620
67.946

38.674
of 26.75 mark 106.582
67.908

26.735 =
Error + 0.054 Error 0.015" in excess

With two telescopes

Reading of 100 mark Barometer 76.710
lower point 34.114
42.596 42.596

Reading of 26.75 mark 106.658
100 " 81.344
25.312 25.312

26.735 = 67.908
Error .015" per indication

The res: of field = $\frac{0.62 \times 3.0}{3.02} = \frac{1.86}{3.02} = 0.51$

" " armature = $\frac{0.3 \times 0.67}{0.97} = \frac{0.201}{0.97} = 0.21$

Res: of machine = 0.74 say 0.80 for margin

12 ampères being required from 120 volt @ M.T. = 30 ω

$\frac{30}{0.80}$ = 37.5 machines with no wire

Each mile of #12 copper wire BWG has a res: of 4.60 = 5% machine so that with one mile of this wire costing £314, 31 machines could be run.

Each mile of #9 copper wire BWG has a res: of abt 2.3 ω = 3 machine so that the wire cost being £68 (about) twice as long a it could be operated at ½ times the wire money

T. 7. 29.	Noon altitude	Sun's lower limit	71° 15′
	"	semi diameter	15.46
		altitude under	71° 30′ 46″
		refraction	26
		true alt:	71° 30′ 20.25
Decl: 9. noon 7. 7. 29		22. 33. 11	22. 18. 29.85
diff for 5 hrs		1.22	
		22. 31. 49	22. 31. 49
			45° 49′ 26″

The error of 15 miles due to twice error of pick prop making altitude too late.

Magnetometer Observations

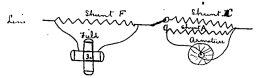
Set up portable magnetometer. Fixed the three main mirrors with their planes at right angles to within two or three minutes also measured the angles between the central clips as follows

Top + center 6° 30′
Centre + bottom 11° 48′

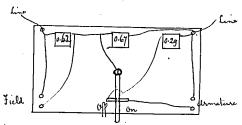
Set the screw of the magnet carriage correctly by ~~magnetometer~~.
Weight of brass cylinder 16.039 gms. Length 3.6 Diam 0.3235″ = 0.8215 cms

Phonograph Series Circuit Arrangement.

Theoretical connections



Practical connections



The exciting current is 4 ampères.

4 × 0.62 = 2.48 volts on the field. 4 × 0.50 = 2.00 on shunted field
4 × 0.67 = 2.61 " " armature 4 × 0.21 = 0.84 armature.
Res: of machine cut out 0.7 ω. current thro field = $\frac{4 \times 0.62}{2.32}$ = 1.17 amp
" " arm = $\frac{4 \times 0.67}{2.32}$ = 1.16.

Magnetic declination and Clock error observed at Eastern corner of Laboratory (Galv room) 7½ July 1889.

By first observation Magnetic declination 7° 30′ W.
second " " " 8° 35′ "
" third " " " 8° 35′ "

Time of third obs: by my watch 10 hr. 12 mins. Measured hour angle 97° 51′ 30″ − 70° 37′ 30″ = 27° 14′ = 1 hr. 48. 56.

True apparent time = 10. 11. 4

Correction to app: time for M.T. at 4 P.M. 282.0 cm
3 hours is 0.5 cm $\frac{1.5}{279.9}$

		4. 40	
True local mean time	10.	15	44
Long. W. of R. Ob.			4. 55. 52
" Greenwich	74° 13′ 30″	1. 00	4. 56. 52
True G.M. mean time	10.	16.	44
Watch showed	10	12.	00
Error of watch in excess		4. 44	
Astronomical clock by comparison with watch		1. 26	fast
Error of clock in excess		2. 18	slow but mine correctly keeping 18 sec error

h m s
1. 0

log 17·79 = 1·25018
2·50036
L tan 11°51′ = 9·32185
3·07239 = 1181·14

log 21·715 = 1·33676
2·67352
L tan 6°31′30″ = 9·05834
3·06862 = 1171·2 10·2

log 17·79 = 1·25018
L tan 11°51′ = 9·32185
0·57203 = 3·73·3

log 21·715 = 1·33676
L tan 6°31′30″ = 9·05834
0·39510 = 2·4844 1·249

P = 8·16 lb.

---

log 17·79 = 1·25018
1·25018
2·50036 = 316·5 − 8·2 = 308·3

log 308·3 = 2·48897
7·98861
= 7·79 = 1·25018
(17·79)² = 2·50036
L tan 11°51′ = 9·32185
13·06100 = 1151 ÷ 2 = 575·5

---

log 5·153 = 0·71206
1·42612 = 26·55
0·7965 × 17·88 = 14·24

log 7·735 = 0·88863
1·77726 = 59·88
26·55
33·33

$\frac{0·93}{402} = \frac{93 \times 10^{-2}}{402} = 2·314 \times 10^{-3} = 8' = \frac{5400}{5400} = 1·0015$

log 5·153 = 1·42612
1·0015 = 0·00065 1·42677
η^2 = 0·99232
μ = 0·60206
I = 1·18351
2·74987
MH = 1·32510 = 21·14

log $\frac{M}{H}$ = 2·76005
M^2 = 4·88515
M = 2·04259 = 110·3
H = 1·28252 = 0·192

L cos 81°27′ = 9·17223
log 2·5028 = 0·39843
9·37066 = ·3721

3·0 × 5·18 × 10⁻³ = 15·54 × 10⁻³ = ·0855
·3876

980·6056
·3876
980·218

Magnetometer Observations

On 11th pier cover with portable magnetometer. 6th July 89

The unloaded tubular magnet was observed with the aid of the chronograph to complete 65 period in 335 seconds = 5·153 sec. The torsion produced by $\frac{\pi}{2}$ twist was $\tan^{-1}\frac{0·03}{50} = 2'$. When loaded with a cylinder whose moment of inertia is known to be 17·88 cm²gm. the magnet completed 51 complete periods in 39 min 6 sec or = 7·735 secs per swing and the torsion produced by $\frac{\pi}{2}$ was $\tan^{-1}\frac{0·93}{402}$.

The deflection readings were for 11°48′ 17·69 + for 6°28′ 21·61
17·95 21·99
17·74 21·67
17·78 21·74
Means 17·79 21·715

The torsion was $\tan^{-1}\frac{1·42}{2}/230$ for $\frac{\pi}{2}$ = 0·00617 = 21′

The correction for these deflections is

$\varphi_1 = \frac{5400}{5400}\varphi = 1·002\varphi$. ∴ φ = 707′ and 390′
707·9 = 11·58′ 390·8 = 6°36′30″

$$p\,\frac{M}{H} = \frac{\frac{\pi^2}{2}(17·79^2)\tan 11°58' - \frac{\pi^2}{2}(21·715)^2\tan(6°36'30'')}{17·79\tan 11°58' - 21·715\tan(6°36'30'')} = 8·16$$

$$\frac{M}{H} = \frac{l}{2}(17·79)^2\tan 11°58'\left(1 - \frac{6·2}{17·79^2}\right) = 575·5$$

The moment of inertia of the magnet is

$$17·88\left(\frac{5·153^2}{7·735^2 - 5·153^2}\right) = 14·24 \text{ cm}^2\text{gm.}$$

The moment from the magnet's proper dimensions is 14·25

The corrected periodic time of the magnet is unloaded

$$t_1^2 = t^2\left(\frac{5400 + \theta}{5400}\right) \text{ where } \theta = \tan^{-1}\frac{0·93}{402} = 1·0015^2$$

$$MH = \frac{4\pi^2 I}{T^2} = \frac{4\pi^2 \times 14·24}{T^2} = 21·14.$$

∴ M = 110 and H = 0·192

Data

The elevation at which the laboratory stands above the mean level of the Atlantic from the county map in the hall of the Y.M.C.A. appears to be 170 feet = 5180 cm.
The latitude is approximately 40°43′30″ N
long. 4h 55m 52s W.

With these values g = 980·6056 − 2·5028 cos 81°27′ − 3·0 × 10⁻³ × 5·18 × 10⁻³

= 980·22

H = 0·192

15 · 29 · 12·6
− 24 · 00
5 · 12·6 = 312·6 ÷ 5·2 = 60 = 312 secs

15 · 32 · 41
29 · 12·6
3 · 25·4 = 205·4 ÷ 5·2 = 40 = 208 secs

Total number of vibs = 40 + 60 + 40 = 140

15 · 32 · 41
− 20 · 32
12 · 09 = 729 secs ÷ 140 = 5·207 secs

log 4 = 0·60206
π² = 0·99430
14·25 = 1·15381
2·75017

log 5·207 = 0·71659
0·71659
1·43318
1·43318
1·31699 = 20·75

17·80³ = 5639·75 log = 3·75126
L tan 11°48′ = 9·31996
3·07122 = 1178·2

3·25042
9·31996
0·57028

3·719
2·4844
1·235

(21·8)³ = 10360 log = 4·01536
L tan 6°30′ = 9·05666
3·07202 = 1180·4 / 1178·2 / 2·2

1·33846
9·05666
0·39512 2·484

2·2 ÷ 1·235 = 1·78

log 0·5 = T. 6989·7
− (17·80)³ = 3·75126
L tan 11°48′ = 9·31996
m/H = 2·77019

2·77019
log mH 1·31699
4·08718
m = 2·04359 110·56
7·27340 0·1877

Magnetometer
Observation in Llewellyn Park. 7th July 89.

Portable Magnetometer. Time 15·0. Temp. 32° C.

Deflection reading

17·89	21·74	
17·78	21·68	
17·73	21·76	
17·81	22·01	
17·80	21·80	angle 6°30′ 11°48′

Vibration reading

			Time	Period	
0	hemit +>	15 · 20 · 32			
10 lf	–	21 · 24·5	52·5	5·25	5·20
20 lf	.	22 · 15·25	54·75	5·075	
40 lf	.	24 · 00	104·75	5·238	
2 lf	. +→	29 · 12·6			
2+10 lf	–	30 · 05·8	53·2	5·32	5·20
2+20 lf	–	30 · 55·4	49·6	4·96	
2+40 lf	.	32 · 48·5	53·1	5·31	
2+80 lf	.	32 · 41	52·5	5·25	

From this series the period is 5·207 secs.
Shortly after loading the magnet the fibre broke.

$$M.H. = \frac{4\pi^2 \times 14{\cdot}25}{(5{\cdot}207)^2}$$

$$= 20{\cdot}75$$

$$P = \frac{(17{\cdot}80)^3 \tan 11^\circ 48' - (21{\cdot}80)^3 \tan 6^\circ 30'}{17{\cdot}80 \tan 11^\circ 48' - 21{\cdot}80 \tan 6^\circ 30'} = -1{\cdot}78 \text{ negligible}$$

$$\frac{m}{H} = \frac{1}{2}(17{\cdot}80)^3 \tan 11^\circ 48'$$

$$= 589{\cdot}1$$

$$m = 110{\cdot}56$$

$$H = 0{\cdot}1877$$

58 29 3202
48 76 1.3
3
93 [illegible] 26.86 = 2.335

Resistances of Plain Meter Plates at No. 2.

Edison Laboratory. – June 29. 1889.

		Out	In	Loss	Gain	per plate Gx.	d' Mean	r	r' = r d / d'
Hot 90°F	1	53825	53963		138	27	111	#1	
		54466	53982	84			122	2.023	R = 2.22
	2	54823	54713	110		20	130	#2	
		53908	53157		149		103	2.029	R = 1.61
32.2°C.	3	50540	50421	119		19	138	#3	
		52970	53126		156		95	2.023	R = 1.40
Cold An 47°F 8.3°C.	4	53643	53570	73		9	82	#4	
		51515	51605		90		121	2.052	R = 3.78
	5	51392	51325	87		2	69	#5	
		52960	53031		71		164	2.010	R = 4.78
	6	54976	54906	70		12	82	#6	
		54410	54504		94		151	1.990	R = 3.66
Ordinary An 75°F 24°C.	7	52946	53070		124	17	108	#7	
		55087	54996	91			125	2.012	R = 2.33
	8	54005	54121		116	14	103	#8	
		52677	52588	89			130	2.027	R = 2.06
Series in hot bath	9	53310	53571		261	25	236	Series	
		50572	50361	211			233		
	10	53250	53546		296	37	229	Series	
		53760	53568	192					

Test extended June 29 – July 10 11 days.

Solution neutral sp. gr. 1.11 mid cold. Hot amalgamation

A repetition of that given on page 114g. It was commenced on the morning of the 3rd July and continued until the 8th July, the total time of working being 109 hours. The current was approximately 3 milliampères and the solution 1.110 slightly acid (1½ drops). Six bottles were employed 3 shunted and three unshunted. The mean temp. was 74° F about or 23.3°C.

No. of plate	Shunt	Res. of shunt	Weight 2. III.	Complete Weight cold	Summ	Weight 8. III.	Complete Weight	Summ	Gain of complete	Gain per plate
1	∞		53.5172	106.6140	106.6143	53.2216	106.6157	106.6152	+0.0012	+0.0006
2			53.0971			53.3936				
3	∞		51.9351	103.5624	103.5661	52.2299		103.5653		
4			51.6310			51.3354			−0.0007	—
5	∞		51.5764	104.4200	104.4205	51.2913	104.4180	104.4184	−0.0016	−0.0008
6			52.8441			53.1371				
7	#4	2.06	53.9835	105.6740	105.6745	53.8500	105.6707	105.6702	−0.0038	−0.0019
8			51.6910			51.8202				
9	#10	2.06	54.2524	108.1158	108.1153	54.1170	108.1150	108.1148	−0.0001	−0.0005
10			53.8649			53.9978				
11	#12	2.06	54.1379	108.6603	108.6608	54.0129	108.6590	108.6592	−0.0011	−0.0006
12			54.5229			54.6463				
									Mean	−0.0005

No. of Plate	Gain	Loss	Mean Gain or Loss	Accepted Full Value W	W − w	(W − w)/w	Res. of bottle	Mean
1	0.2965		0.2961					
2		0.2956						
3	0.2948		0.2952	0.2951				
4		0.2956						
5	0.2930		0.2940					
6		0.2951						
7		0.1335	0.1334		0.1637	1.246	2.587	
8	0.1292							
9	0.1329	0.1334	0.1332		0.1619	1.215	2.503	2.635
10								
11	0.1264	0.1250	0.1242		0.1709	1.376	2.834	
12								

When $d = 0.3''$ $f(d)$ approximates by trial to $d^{\frac{1}{2}}$

$$\therefore \quad D \cdot 3 \left(\log_e \frac{D}{d}\right)^{-\frac{1}{2}} = 0.3^{\frac{1}{2}}$$

$$\therefore \quad \log_e \frac{D}{d} = 0.3^{\frac{1}{2}}$$

$$\log_e \frac{D}{d}^{-1} = 0.3444$$

$$\log_e \frac{D}{d} = 3.73$$

$$\log \frac{D}{d} = 1.669 \ * \qquad \frac{D}{d} = 28.06 \qquad D = 8.5$$

When $d = 0.1$ $\frac{D}{d} = 8.09$ $\log_{10} \frac{D}{d} = 1.9294$ $\log_e \frac{D}{d}$ 4.4444 $\left(\log_e \frac{D}{d}\right)^{\frac{1}{2}} = 2.114$ $\left(\log_e \frac{D}{d}\right)^{\frac{1}{2}} = 0.473$

$$d\left(\log_e \frac{D}{d}\right)^{-\frac{1}{2}} = 0.0474$$

When $d = 0.2$ $\frac{D}{d} = 12.8$ $\log_e \frac{D}{d} = 1.6294$ 3.75 1.94 0.516

$$d\left(\log_e \frac{D}{d}\right)^{-\frac{1}{2}} = 0.103$$

When $d = 0.3$ $\frac{D}{d} = 26.3$ 1.4519 & 3.3444 1.83 0.546

$$d\left(\log_e \frac{D}{d}\right)^{-\frac{1}{2}} = 0.164$$

When $d = 0.4$ $\frac{D}{d} = 21.25$ 1.327 3.056 1.75 0.571

$$d\left(\log_e \frac{D}{d}\right)^{-\frac{1}{2}} = 0.228$$

With these values and the curve for 20°C wires we have on looking 0.5" diam as standard

0.1"	Around	31	Calculated	140
0.2"	"	86	"	86.7
0.4"	"	216	"	192

Owing to the conductivity of air carrying into account (thermal) to different degrees with different wires, the formula cannot be expected in any case to apply rigorously

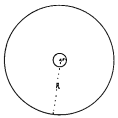
Magnetic Measurements

Made near Bechtelsville Berks Co. Pennsylvania July 89.

A magnet suspended by a fibre about its centre which made 50.5 complete swings in 5 mins in Shewellyn Park where the Horizontal component is 0.188 gave 51 complete swings in that time at some distance from disturbing forces near Gilbert's mine Pa. but in one place near the bottom of a shaft at the top of the same hill and right in the back of the magnetite bed it executed 121 complete swings in that time. The horizontal component at that spot in the mine must thus have been approximately $\left(\frac{121}{50.5}\right)^2 \times 0.188 = 1.080$

A dipping needle about 8 cms long and almost balanced when held vertically gave dip as high as 10° and in one or two instances even 25° in the neighborhood of ore.

The following problem presents itself in the preliminary mathematical investigation of the ∮ carrying capacity of moulded conductor.



Let a conductor of radius r be enveloped by a homogeneous cylindrical mass of radius R of non conducting material. Let a current c traverse the conductor until the permanent state is indefinitely closely approached. Let the exterior temperature of the envelope be τ. Required the interior temperature when k is the thermal conductivity of the envelope.

The energy developed per unit length of conductor is $\frac{c^2\rho}{\pi r^2}$ where ρ is the resistivity of the conductor and the heat developed in unit time is $\frac{c^2\rho}{J\pi r^2}$ therms.

At any distance σ from the centre let a circle be drawn and a cylinder of unit length erected on this circle. Then the heat escaping across this unit area of this cylinder in unit time is $-k\frac{d\theta}{d\sigma}$ and the total flux is thus $-\frac{2\pi k\sigma\, d\theta}{d\sigma}$

This must be the heat generated in the wire. Hence

$$\frac{c^2\rho}{J\pi r^2} = -2\pi k\, d\theta \frac{\sigma}{d\sigma}$$

$$\therefore \quad d\theta = \frac{-c^2\rho}{2Jk\pi^2 r^2} \frac{d\sigma}{\sigma}$$

$$\theta = \frac{-c^2\rho}{2Jk\pi^2 r^2} \times \log_e \sigma + a$$

when $\sigma = R$

$$\theta = \tau$$

$$\tau = \frac{+c^2\rho}{2Jk\pi^2 r^2} \times \log_e \frac{1}{R} + a$$

$$\therefore \quad \theta = \frac{c^2\rho}{2Jk\pi^2 r^2}\left(\log_e \frac{1}{r} - \log_e \frac{1}{R}\right) + \tau$$

$$= \frac{c^2\rho}{2Jk\pi^2 r^2}\left(\log_e \frac{R}{r}\right) + \tau$$

$$\theta - \tau = b\frac{c^2}{d^2} \log_e \frac{R}{d}$$

when $R = \infty$

$$\theta - \tau = b\frac{c^2}{d^2}\left(\log_e \frac{1}{d} - 1\right)$$

so that the rise of temperature would vary as the square of the current and nearly in inverse proportion to the square of the diameter for small wires

$$c^2 = \frac{\theta - \tau}{b}\left(\frac{d^2}{\log_e \frac{R}{d} - 1}\right)$$

$$c = \sqrt{\frac{\theta - \tau}{b}}\; d \times \left(\log_e \frac{R}{d}\right)^{-\frac{1}{2}}$$

July 17th Wednesday. **Physiological Experiments**

Took the following measurements of the resistance of different persons in the Laboratory under the following conditions. Two bichromate battery jars were nearly filled with a solution of $Zn\,SO_4$ and two more with solution of crude K.HO. The density of the $Zn\,SO_4$ solution was 1.120 - - - - - K.HO - 1.10

The hands after being washed were immersed vertically downwards into these jars until the tips of the fingers rested on the bottom. The surface of the liquid then reached about as far as the pulse of the wrists. The measurement was first made in $Zn\,SO_4$ and then in the K.HO with the hands washed between the tests. The Wheatstone's bridge and deadbeat galvanometer on the first table were used, with 4 Fuller cells 100/1000 and imp: z: observations. The results are thus independent practically speaking of polarization. The resistances were observed after about 30 seconds immersion but continued to reduce beyond that period.

No. of Obs.	Name	Age	Height	Weight lb	Resistance $Zn\,SO_4$	Resistance K.HO.	Difference	v = M − 905 K.HO	$\frac{\Sigma v \times 0.6745}{\sqrt{n(n-1)}}$	$\frac{0.6745\,\Sigma v}{\sqrt{n(n-1)}}$
1	Dean	42	5·2½	115½	1350	950	400	+ 45	22·1 ±	139 ±
2	Ott	39	5·4	142	1250	850	400	− 55		
3	Lehmann	20	5·3	138	1200	800	400	−105		
4	Lassetz	32	5·7	122	1250	920	330	+ 15		
5	Gogard	33	5·4	126	1220	870	350	− 35		
6	Kilpper	33	5·8½	156	1200	870	330	− 235		
7	Hiffle	34	5·5½	130	1470	820	650	− 95		
8	Schaffner	33½	5·9	146	1000	670	330	−235		
9	Heiser	41	5·5	180	1310	700	610	−205		
10	Miller	20	5·8	122	1090	880	210	− 25		
11	Aylworth	20	5·9½	139	1250	1000	250	+ 95		
12	Logue	42	5·7½	155½	1440	880	560	− 25		
13	Fox	29	5·6½	125	1710	1000	710	+ 95		
14	Rundlett	25	5·4	138	960	600	360	−305		
15	Dowell	22	5·4½	135	900	550	350	− 355		
16	McGinn	27	5·5	122	1430	870	560	− 35		
17	Whittemore	37	5·9	142	1240	650	590	−455		
18	Cobb	49	5·9½	147	1030	670	360	− 235		
19	Neubert	37	5·3½		1090	790	300	− 115		
20	Read	18	5·10	121	1170	1070	100	+ 165		
21	Huffmeier	25	5·10	126	1400	1000	400	+ 95		
22	Wesby	48	5·4	140	820	520	300	− 285		
23	Hastings	40	5·2	140	1520	1000	520	+ 95		
24	Dixon	30	5·10	137½	1460	1070	390	+ 165		
25	Brown	42	5·7	125	1470	1090	380	+ 185		
26	Rehr	48	5·4	141	1610	1250	360	+ 345		
27	Nickon	27	5·11½	140	1440	1130	310	+ 225		
28	Frickhow	23	5·9	137	1500	1170	330	+ 265		
29	Doehler	25	5·11½	132½	1280	1070	210	+ 165		
30	Rockwell	29	5·10	170	1370	960	410	+ 55		
31	Ott	38	5·5½	135	1800	1320	480	+ 415		
32	Lord	59	5·6½	150	1380	910	470	+ 5		
33	Donovan	20	5·7	144	1230	850	380	− 55		
34	Rotsbeter	43	5·4	130	1230	950	280	+ 45		
35	Dahl	35	5·9	147	1200	650	550	− 255		
36	McCrank	19	5·6	119	1350	920	430	+ 15		
37	Luddke	18	5·6	122	1650	1400	250	+ 495		
38	Magee	37	5·11½	156	1040	720	290	− 155		
39	Fessenden	22	6·0½	165	1220	1090	130	+ 185		
					50560	35370	15190	Σ v		
				Mean	1296	905	391	= 6325		
							of difference 30%	= 162 ± average discrepancy		
				Maximum	1800	1400				
				Minimum	820	520				

Physiological Experiments.

July 19th Friday

Took the Carpentier D'Arsonval galvanometer, and a Wheatstone Bridge ~~[illegible]~~ to the Phonograph Works and set them up in the Testing Room there. Used four phonograph cells of the chromic acid type. Filled up two tall and glass jars as in the preceding test with a solution of crude H_2O of density 1.10 and changed the solution in the afternoon. Each man washed his hands & dried them before immersing them ~~[illegible]~~ pointing vertically downward in the jars until the tips of the fingers rested on the bottom. The bridge ratio was 1000/100 no shunt capable of reading to single ohms and observation was made to one F.E. The current was applied on the average for about thirty seconds. The surface of the solution reached as a rule the pulse of the wrists.

No. of Obs.	Name	Age	Weight	Height	Res:	Variation from 1000	No. Volume 900 1100 ±15	
1	Osborne	25	143	5.10½	1170	170		
2	Ballins	33	148	5.7	930	70		
3	Barry	34	104	5.5½	1130	130		
4	Garcia	20	109	5.5½	1590	590		
5	Muchmore	29	123	5.6½	1090	90		
6	Richelton	45	137	5.8½	870	130		
7	Oxley	22	133	5.9½	980	20		
8	McNab	21	127	5.9	1060	60		
9	Thrige	23	125	5.7	1570	570		
10	Sandford	51	200	5.7	660	340		
11	Smith	33	175	5.11	840	160		
12	Gandegger	20	150	5.11	900	100		
13	Jaeger	22	136	5.10	1120	120		
14	Archer	22	112	5.6	1160	160		
15	Barne	20	122	5.9	1000	0		
16	Wagner	27	123	5.8½	1160	160		
17	Jordon	34	122	5.7	1030	30		
18	Tremayne	19	150	5.10	1050	50		
19	Bonett	28	138	5.4	1010	10		
20	Gadetten	21	146	5.10½	950	50		
21	Owen	19	122	5.8	1160	160		
22	Payne	21	121	5.10½	1230	230		
23	Mike	34	160	5.9	960	40		
24	Pixley	20	151	5.9½	1080	80		
25	Sandford	28	132	5.5½	990	10		
26	Van Halfen	28	139	5.5½	980	20		
27	Nelson	19	119	5.6	1010	10		
28	Francisco	22	131	5.9½	1000	0		
29	Thurman	20	118	5.10	1400	400		
30	Wagner	29	121	5.8	1110	110		
31	Harris	20	137	5.11	1310	310		
32	Miller	20	159	6.2⅞	1210	210		
33	Pettit	24	116	5.4	930	70		
34	Wells	21	125	5.3	1160	160		
35	Kenny	27	135	5.6½	1140	140		
36	Stocker	26	126	5.8	1080	80		
37	Seward	23	131	5.6	1060	60		
38	Johnson	29	135	5.9	1030	30		
39	Sargent	41	110	5.1	870	130		
40	Hasselant	32	192	6.1	870	130	29	
					42,850	5390	15	

No. of Mn.	Name	Age	Weight	Height	Res: 42850	Aggregation from 1000 5390	No between 900 & 1100 25
41	Holewell	21	150	5.10	1970	970	
42	Atwood	26	141	5.10	920	80	
43	English	34	131	5.7	890	110	
44	Nehringer	26	139	5.9	1280	480	
45	Butler	24	137	5.8	790	210	
46	Duffy	27	125	5.7	1120	120	
47	Sofie	17	97	5.6	1210	210	
48	Ferrel	19	132	5.9	1060	60	
49	Adye	30	127	5.10	1000	0	
50	Fohnlein	34	127	5.7	950	50	
51	Ward	11	68	5.1	1150	150	
52	Flinn	17	96	5.2	1030	30	
53	Jones	16	103	5.3	960	40	
54	McLaughlin	18	117	5.7	1000	0	
55	Bennett	19	130	5.9	1010	10	
56	Kennedy	17	120	5.8	960	40	
57	Condit	15	93	5.1½	1040	40	
58	Burnes	22	127	5.9½	950	50	
59	Neary	18	129	5.8	870	130	
60	Kingsbury	25	134	5.8	1030	30	
61	Wheeler	25	122	5.9½	760	240	
62	Riker	15	121	5.8	1150	150	
63	Gibbons	32	165	5.6	850	150	
64	Walter	19	106	5.6½	1100	100	
65	Dainty	34	145	5.7½	860	140	
66	Henderson	25	153	5.7½	850	150	
67	Sloane	27	139	5.5	890	110	
68	Agin	15	75	4.11	1500	500	
69	Markwith	20	121	5.4	1150	150	
70	Gray	30	124	5.7	1010	10	
71	Wright	26	150	5.11	1100	100	
72	Gallagher	27	159	5.9	990	10	
73	Kihen	21	135	5.7	750	250	
74	Jennings	22	106	5.6	1020	20	
75	Rogan	21	135	5.8	1010	10	
76	Belingi	25	135	5.7	1130	130	
77	Nenninger	27	129	5.8	1190	190	
78	Ferguson	23	126	5.8½	1280	280	
79	Smith Jr.	43	191	5.10	950	50	
80	Pfaff	32	158	5.5½	720	270	
81	Kolgin	22	152	5.9½	1000	0	
82	Nolge	20	144	5.7	1120	120	
83	Dudley	32	119	5.6½	1100	100	
84	Kleffel	36	174	5.8	810	190	
85	Dibble	24	129	5.4½	1020	20	
86	Pack	24	133	5.10¾	900	100	
87	Studer	30	144	5.4	750	250	
88	Stroebing	36	145	5.6	830	170	
89	Weldon	26	178	5.11	780	220	
90	Schindler	23	141	5.6	870	130	
91	Cooth	37	130	5.9	1040	40	
92	Luhr	18	130	5.9½	1070	70	
93	Friel	22	136	5.9	850	150	
94	Rettig	20	113	5.8	940	60	
95	Wolfing	29	162	5.6½	660	340	
96	Renyhan	25	135	5.7	930	70	
97	Schaffleinger	27	144	5.8	800	200	
98	Iplinger	39	130	5.6	770	230	
99	Mack	21	137	5.6	870	130	
100	Young	23	150	5.7½	870	130	
					102490	13930	42

No. of Ch.	Name	Age	Weight	Height	Res.	Expiration Forced 1000	Nebulosum 900 + 100
				' "	102490	1930	62
101	Zoller	39	136	5·8	840	160	
102	Becker	19	124	5·4	870	130	
103	Rymer	21	112	5·5½	1010	10	
104	Alley	21	121	5·7¼	1060	60	
105	Hammond	25	160	5·7	920	80	
106	Graham	22	145	5·11½	990	10	
107	Meyer	33	143	5·3	780	220	
108	Bulkhalle	22	160	5·9	750	250	
109	Jacobs	21	125	5·8½	950	50	
110	Kototzky	29	151	5·5½	900	100	
111	Mc Intosh	26	134	5·7	910	90	
112	Vaughan	23	170	5·7½	740	260	
113	Fulton	24	178	6·1	870	130	
114	Pitten	23	114	5·6½	1060	60	
115	Fuchs	25	160	6·1	1060	60	
116	Titus	34	160	5·5	830	170	
117	Snider	29	143	5·5	820	180	
118	Spies	48	122	5·10½	770	230	
119	Sherman	20	148	5·9½	850	150	
120	Dielenbacher	19	134	5·5	1000	0	
121	Aldat	19	109	5·4	940	60	
122	Aliffh	32	122	5·4	780	220	
123	Gordan	16	123	5·7½	1270	270	
124	Gannon	28	112	5·4½	950	50	
125	Thorpe	22	136	5·8½	820	180	
126	Schwab	17	115	5·2	950	50	
127	Edwards	18	120	5·7	1180	180	
128	Dickerson	16	118	5·9½	1010	10	
129	Howard	17	111	5·5½	1450	450	
130	Flinn	21	147	5·7	1040	40	
131	Barnard	21	140	5·6	850	150	
132	Hammer	28	149	5·8½	840	140	
133	Jordan	14	69	4·10	1650	350	
134	Mafey	25	133	6·0	1100	100	
135	Kane	19	119	5·6	1050	50	
136	Withey	33	144	5·7	1000	0	
137	Gerry	16	110	5·6½	920	80	
138	Young	26	144	6·0	1000	0	
139	Bishop	19	129	5·10	1320	320	
140	Schreiber	30	185	5·10½	750	250	
141	Attenhaus	22	192	5·10	870	120	
142	Kolb	31	150	5·7	980	20	
143	Mc Elroy	35	164½	5·9	840	160	
144	Savage	36	183	5·7	810	190	
145	Keenan	27	125	5·8	1020	20	
146	Chandler	38	154	5·10½	970	30	
147	Pierson	22	125	5·6½	1080	80	
148	Rotfearn	15	103	5·5	1070	70	
149	Weitz	40	186	5·10	820	180	
150	Howatt	20	138	5·9½	1050	50	
151	Ritz	27	176	5·10½	930	70	
152	Aymer	32	179	5·10	860	140	
153	Kearney	35	134	5·4	940	60	
154	Bradley	23	158	5·11	1000	0	
155	Kolb	30	166	5·3	1280	280	
156	Kinghorn	25	171	5·10	950	50	
157	Fitzgerald	28	148	5·7½	1050	50	
158	Shay	36	119	5·5	880	120	
159	Beck	21	133	5·4½	1100	100	
160	Harper	26	102½	5·2½	1050	50	33
					160910	28150	95

No. of Obs	Name	Age	Weight	Height	Rec.	Variation from 1000	No between 900 & 1100 yes
					160910	21170	
161	Conolly	18	117	5·6	1090	90	
162	Hutchinson	30	124	5·6½	830	170	
163	Littell	14	81	5·1	1290	290	
164	Spencer	28	120	5·5½	1050	50	
165	Nolans	20	158	5·11	850	150	
166	Mack	39	154	5·7½	850	150	
167	Wald	17	128	5·8	1050	50	
168	Hooper	22	131	5·8	990	10	
169	Kitchell	21	124	5·7	1130	130	
170	Oran	25	132	5·9	1000	0	
171	Byrnes	35	129	5·10	840	160	
172	Lanzet	39	139	5·8	950	50	
173	Marshat	26	140	5·9	850	150	
174	Farnham	22	153	5·10	860	140	
175	Bennett	24	131	5·4½	1020	20	
176	Hessdorfer	33	119	5·6	910	90	
177	Gamble	27	120	5·5½	960	40	
178	Forster	21	125	5·8	920	80	
179	Taney	39	125	5·6	930	70	
180	Riell	26	149	5·11	950	50	
181	Devine	18	103	5·1	1330	330	
182	Greer	19	145	5·9½	1420	420	
183	Ohaus	19	144	5·9½	1150	150	
184	Goodwin	19	109	5·2	930	70	
185	Vannees	23	126	5·5	1180	180	
186	Winter	32	132	5·6	1030	30	
187	Hall	33	137	5·10	1050	50	
188	Dalrymple	22	132	5·8	1300	300	
189	Kidd	28	109½	5·6½	850	150	
190	Hawes	26	124	5·7	1170	170	
191	Edge	27	133	5·6½	1030	30	
192	Mortimer	18	116	5·5½	1050	50	
193	Burke	21	130	5·7	940	60	
194	Martin	25	144	5·10½	930	70	
195	Lyon	17	122	5·6½	880	120	
196	Hagan	42	161	5·6	900	100	
197	Hefron	19	116	5·5½	1000	0	
198	Barker	21	159	5·9	770	230	
199	Cutter	45	143	5·5½	850	150	
200	Haney	25	130	5·10	1000	0	
201	Grove	18	110	5·4½	1200	200	
202	Hayden	30	130	5·10½	820	180	
203	Knight	28	127	5·8	1170	170	
204	Schuan	32	128	5·5	830	170	
205	Daly	30	130	5·6½	950	50	
206	Holmbie	18	176	6·0½	1000	0	
207	Hamell	21	143	5·11	1050	50	
208	Welch	20	138	5·7½	880	120	
209	Higginbotham	16	109	5·4	1030	30	
210	Hillmett	39	113	5·7½	1010	10	
211	Rosel	17	124	5·7	1050	50	
212	McCundy	30	147	5·7	1100	100	
213	Blauan	24	142	5·11	670	330	
214	Alford	33	177	6·0	940	60	
215	Stewart	25	154	5·6	910	90	
216	Richard	46	150	5·9½	950	50	
217	Corby	33	186	5·11½	820	180	
218	Lawler	26	152	5·9	890	110	
219	Jacobsen	28	148	5·9	850	150	
220	Kreelicher	39	146	5·5	930	70	33
					220,140	2,140 20	128
	$\frac{220,140 + 38,310}{229} = 986$			Mean	10005	127	

Physiological Experiments

Resumé of results.

The number of cases tested in the Laboratory was 39
- - - - - - Factory - 220
- total - - - 259

The mean resistance of the Laboratory men 905 ω
- - - - Factory - 1000.5 ω
- - - - both 986 ω

Taken all together the results were

Between	500 ω	and	600 ω	2	cases
-	600 ω	-	700 ω	9	- 3
-	700 ω	-	800 ω	17	- 4
-	800 ω	-	900 ω	35	- 47
-	900 ω	-	1000 ω	53	- 47
-	1000 ω	-	1100 ω	69	- 60
-	1100 ω	-	1200 ω	20	- 28
-	1200 ω	-	1300 ω	9	- 8
-	1300 ω	-	1400 ω	5	- 4
-	1400 ω	-	1500 ω	5	- 4
-	1500 ω	-	1600 ω	3	- 3
-	1600 ω	-	1700 ω	1	- 1
-	1700 -	-	1800 ω	0	- 0
-	1800 -	-	1900 ω	0	- 0
-	1900 -	-	2000 ω	1	- 1
				259	220

Taking the factory results $\Sigma v = 27920$

$\frac{0.81453\ \Sigma v}{\sqrt{220 \times 219}} = 107.6\ \omega$

that is to say by the theory of errors half the cases should fall within 107.6 ω of 1000 or from 893 to 1107 and as a fact 113 (111) could fall between 900 and 1100.

$\frac{0.81453\ \Sigma v}{220\ \sqrt{219}} = 7.25$

$h = \frac{0.6769}{10\ 7.25} = 0.0\cancel{6}\cancel{4}\cancel{4}93$

					Theoretical	actual
$x = 100$	$hx = 0.0\cancel{4}\cancel{4}93$		$y = 0.1469$	103.	103	107
$x = 200$	-	$= 0.8866$	$y = 0.790$	174	71	75
$x = 300$	-	$= 1.3299$	$y = 0.940$	207	33	22
$x = 400$	-	$= 1.7732$	$y = 0.988$	217	10	7
$x = 500$	-	$= 2.2165$	$y = 0.998$	219.5	2.5	4
$x = 600$	-	$= 2.65$	$y = 0.999$	220	0.5	4
						3
						1

The theoretical distribution of the variations on the theory of errors thus agrees fairly with the observed distribution.

Range	Number	x	hx	y	ε	d	obd.	d	obd
0 - 50	47	50	0.22.16	0.2459	54.8	54	47		
50 - 100	56	100	0.44.33	0.4693	103	49	~~[illegible]~~ 56	103	103
100 - 150	~~38~~	150	0.66.49	0.6531	144	41	38		
150 - 200	40	200	0.8866	0.7900	174	30	~~33~~ 40	71	78
200 - 250	13	250	1.1081	0.8826	194	20	13		
250 - 300	10	300	1.3300	0.9400	207	13	10	33	23
300 - 350	7	350	1.5516	0.9722	214	7	7		
350 - 400	1	400	1.7732	0.988	217	3	1	10	8
400 - 500	~~3~~ 4	500	2.2165	0.998	219.6	2.6	4	2.6	4
~~500 - 600~~	~~3~~	600	2.65	0.9999	220	0.4	4	0.4	4
over	~~4~~ 4	∞							

Physiological Experiments.

July 20th Saturday

Tested the resistance offered by a man's body under the following conditions. Two half jars containing KHO solution density 1.10 were employed with the usual copper plates. The EMF was 4 Fuller cells (8 volts) a res: and the Einhoff galvo were inserted between the bridge and battery so as to adjust the current. The following results were then obtained in m: f.z.

No. Obs.	Milliamp. Res. 6	Res. obt.	Milliamp. Res. patient	E.M.F. on patient	Impression	Mean.	Area of skin in sq. cm.	Res: of sq. cm. skin	Res: of body	Error of mean obs.
1	0.6	510ω	0.3	0.15 volt	3½" above ulnar condyle					
2	6.0	510ω	3.0	1.5						
3	6.0	620ω	3.0	1.9	ulnar condyle					
4	5.5	785ω	2.75	2.0	3rd phalanx middle finger					
5	5.0	925ω	2.5	2.3	2nd phal.					
6	4.5	1020	2.25	2.3	1st do.	1020	4B	54,200ω	4.20ω	± 40ω.
7		965			2nd "	940	150			
8		815			3rd do	800	370			
9		635			ulnar condyle	627	730			
11		475			3½" above wrist	497	900			

The girth at the condyle was 7" = 17.8 cms
- - - - point 3½" above - 8" = 20.3 cms
Mean 19.0 - × 3.5 × 2.54 = 169 sq. cm.

Took a pair of white kid gloves; put them on the hands and marked off roughly the lines corresponding to the above measures. Then weighed the gloves, the sections cut off between these lines and a plane measured area as follows.

Glove no 1

Portions	Observed weight	Weight per sq. cm.	Area	Total
Tips	1.035		46.2	
1-2 Phals.	2.350		104.9	151.1
2-3 Phals	4.855		216.7	367.8
3- Condyle	7.795		348.0	715.8
	16.035		715.8	
Wt. whole glove	16.040			
Wt. of palm	0.045	0.0224		

Glove no 2

Portions	Observed weights	Weight per sq. cm	Area	Totals
Tips	0.880	40.0	40.0	
1-2 Phal.	2.335	106.7	106.1	146.1
2-3 "	4.800	218.2	218.2	364.3
3- Condyle	8.265	375.7	375.7	740.0
	16.280		740.0	
Wt. whole glove	16.220			
Wt. of 10×13 cm	2.865	0.0220		

Mean values are in To tips 1st Phalanges 43.1 say 43
2nd " 148.6 149
3rd " 366.1 366
Condyle 728. 728
3½" Wrist 897 900

Physiological Experiments.

With the results at the foot of the last page we have

Where x is the res: per unit surface of skin and y half the interior res: of the body.

$$\frac{x}{43} + y = 510 \quad (1)$$
$$\frac{x}{150} + y = 470 \quad (2)$$
$$\frac{x}{370} + y = 400 \quad (3)$$
$$\frac{x}{730} + y = 313.5 \quad (4)$$
$$\frac{x}{900} + y = 246 \quad (5)$$

$$x + 43y = 21930 \quad (6)$$
$$x + 150y = 70500 \quad (7)$$
$$x + 370y = 148000 \quad (8)$$
$$x + 730y = 228800 \quad (9)$$
$$x + 900y = 221400 \quad (10)$$
$$5x + 2193y = 690630 \quad (11)$$

$$43x + 1849y = 942990 \quad (12)$$
$$150x + 22500y = 105750000 \quad (13)$$
$$370x + 136900y = 54760000 \quad (14)$$
$$730x + 532900y = 167022400 \quad (15)$$
$$900x + 810000y = 199260000 \quad (16)$$
$$2193x + 1504149y = 432561990 \quad (17)$$

from (17) $\quad x = 197247 - 685.9y$

(11) $\quad 986235 - 3429.5y + 2193y = 690630$

$$1236.5y = 295605$$
$$y = 239.1 \quad (18)$$

$2y$ the res: of the body $= 478$ ω

$$x = 197247 - 163971$$
$$= 33276 \quad \text{say } 33300 \text{ ω} \quad (19)$$

$$774 + 23g = 1013 \qquad x - M = +503 \quad (20)$$
$$222 + 23g = 461 \qquad = -g \quad (21)$$
$$90 + 23g = 329 \qquad = -71 \quad (22)$$
$$46 + 23g = 285 \qquad = -28.5 \quad (23)$$
$$37 + 23g = 276 \qquad = +30 \quad (24)$$

$$v^2 = 25300g$$
$$81$$
$$50241$$
$$812$$
$$900$$
$$259,843$$

$\sqrt{\ } = 510 \times 0.3894 = 198.6 \pm$ as the error of one obs:

If however we omit equation (1) we have for the normal equation

$$42x + 21500y = 668700 \quad (25)$$
$$21500x + 1502300y = 431,619,000 \quad (26)$$

from (26) $\quad x = 200753 - 698.7y$

$$803012 - 279745y + 21500y = 668700$$
$$6244.8y = 135312 \qquad y = 209.8 \quad (27)$$
$$x = 200753 - 146587 = 54,166. \quad (28)$$

from (27)·(28)

$$361 + 210 = 571 \quad = +101 \qquad 10201 \qquad 58.5 \times 1.6745$$
$$146 + 210 = 356 \quad = -44 \qquad 1936 \quad = 39.5$$
$$74 + 210 = 284 \quad = -20 \qquad 900$$
$$60 + 210 = 270 \quad = +24 \qquad 576 \quad \text{mean error of each obs:}$$
$$\Sigma v^2 = 13613$$
$$\Sigma v = 117$$

$116,456g.r.0 + 315,182,540 = 431,639,440.$

On the winding of a large radial (Ore-Milling) Electric Magnet

Twenty radial slots of cast iron project from a cylinder of 25" (60 cm) external diameter. Each slot is 32" wide 6" deep and 2" thick; separated at the surface of the cylinder by a distance of 1¾". Required the most effective winding.

Let d be the diam. of the conductor
ρ - its resistivity
t - its covering thickness
k - the ailing space
a - - length of each turn (average)
l - - total length of wire on each slab
c - - current
E - - emf in each slab.
n - no. of turns

Then $l = \dfrac{k}{(d+t)^2}$

$n = \dfrac{l}{a} = \dfrac{k}{a(d+t)^2}$

ampere turns $= \dfrac{cl}{a} = \dfrac{ck}{a(d+t)^2}$

but $c = \dfrac{E}{\frac{4l\rho}{\pi d^2}} = \dfrac{E\pi d^2}{4l\rho} = \dfrac{E\pi d^2(d+t)^2}{4\rho k}$

$\therefore$ ampere turns $= \dfrac{E\pi d^2}{4a\rho}$ which increases indefinitely with d.

The limit is found in the heating of the wire

Suppose the current limit to be 10 amperes, and suppose each quadrant of 5 slabs to be joined in parallel then the p.d. on each slab will be $\frac{100}{5} = 20$ volts and the res. $= 2\,\omega$.

$$\therefore \frac{k}{(d+t)^2} \times \frac{4\rho}{\pi d^2} = 2\times 10^3$$

$$\pi(d+t)^2 d^2 = \frac{4\rho k}{2\,10^3}$$

$$(d+t)\,d = \sqrt{\left(\frac{4}{\pi}\frac{\rho k}{10^3}\right)}$$

$$d^2 + td + \frac{t^2}{4} = \frac{t^2}{4} + 10^{-3}\sqrt{\frac{\rho k}{5\pi}}$$

$$d = -\frac{t}{2} \pm \sqrt{\left\{\frac{t^2}{4} + 10^{-3}\sqrt{\frac{\rho k}{5\pi}}\right\}}$$

Here t is 0·02
ρ is 1600
k is $311 \times 16\cdot 2g = 5000$ $\quad (0\cdot 75'' \times 6g \times 6) = 311$

$\dfrac{\rho k}{5\pi} = \dfrac{5000{,}000}{15708} = 5094{,}400$ $\quad \sqrt{\ } = 7114 \times 10^{-4} = 0\cdot 07114$
$= \dfrac{0\cdot 0004}{0\cdot 07148} = 7\cdot 18 \times 10^{-2}$

$t^2 = 4\cdot 0 \times 10^{-4}$ $\quad \sqrt{\ } = 2\cdot 68 \times 10^{-1}$

$d = 0\cdot 2268 - 0\cdot 01 = 0\cdot 2258$ cm $= 0\cdot 102''$
$=$ midway between 12 + 13 wire B.W.G.

Let us take # 12 which is 0·109" + covered 0·117".

$(0\cdot 117)^2 = 0\cdot 01369$

$\dfrac{300}{0\cdot 01369} = \dfrac{3\cdot 0 \times 10^2}{1369 \times 10^{-4}} = 2\cdot 19 \times 10^4$ inches $= 1\cdot 83 \times 10^3$ feet 1830

$8\cdot 69 \times 10^{-4} \times 1\cdot 83 \times 10^3 = 1\cdot 59 \times 10^{-1} = 1\cdot 6\,\omega$.
$1\cdot 83 \times 10^3 \times 3\cdot 60 \times 10^{-4} = 6\cdot 59 \times 10^{-1} = 65\cdot 9$ lbs say 66 lbs per slab
$= 1320$ lbs of # 12 wire in all.

Physiological Experiments.

To ascertain the amount of heat generated by a given current beyond dispute, for presentation to the electrocide commission took a glass tube 175 cms long and 4·8 cms internal diam. Passed a wire carrying a zinc disk electrode watertight through a rubber stopper and filled the tube to within a few cms of the top with 5 lbs 7 ozs = 2495 grammes of $ZnSO_4$ solution density 1·012 = 2466 c.c. A zinc leclanché rod was plunged into the solution for about 8 cms at the top. The res. of this vertical column was observed to be 119·5Ω @ 25°C. A standard thermometer was suspended with its bulb half way down the tube.

The 1200 volt dynamo was connected up with the tube at 4 o'clock through the Ayrton galvanometer. The P.D. on the tube was observed by potentiometer to be

$$\frac{1{\cdot}426 \times 200{\cdot}218}{218} = 1310$$

the current should have been $\frac{1310}{1195} = 1{\cdot}096$ ampères.

It was observed to be $\frac{0{\cdot}22}{0{\cdot}195} = 1{\cdot}128$ ampère.

The current was applied for sixty second.

At the end of that time the Ayrton reading was 0·224 = 1·23 amp

and the p.d. $\frac{1{\cdot}426 \times 200{\cdot}224}{224} = 1275$ volts

The observed resistance was 1040Ω so that the final current strength should have been by calculation 1275/1040 = 1·226

The mean strength of current was 1·18 ampères.

" p.d. 1293 volts

" energy developed in the tube was 1293 × 1·18 × 60 = 91560 Joules

= 21800 thermes ÷ 2495 = 8·74° C rise assuming sp. heat of solution = 1·0 " The actual rise of temp. was to 33·0°C = 8·0°C.

Stretched 146·5 metres 151·6 feet of platinoid wire 0·011" up and down the galvanometer room. Checked the Cardew voltmeter by setting it across the 112 volt mains = 181°. Voltmeter indication on alternating electrodes = 112° = 95 − 9·5 = 85·5 volts. Set two jars of caustic potash solution one at one end of the fine wire and the other on a movable contact. Found that 2·2 metres was all I could fairly stand without inconvenience. Lehmann took about 3·2 metres. These voltages are $\frac{2{\cdot}2 \times 85{\cdot}5}{146{\cdot}5}$ and $\frac{3{\cdot}2 \times 85{\cdot}5}{146{\cdot}5}$ = 4·0145 and 5·885

Particulars of the new phonograph governor shunt.

Length 28" = 71·5 cms platinoid wire 0·018" diam. res: 1·65Ω

Physiological Experiment.

Took a series of resistances of five men under certain conditions as follows:- Two # 11 B.W.G wire 0·12" diam were connected with the Wheatstone Bridge terminals. The extremities were bared for 6 inches or so. A sheet of tinned iron 20" × 20" was also provided. The routine was as follows. Each man

1st (a) held the wire between finger thumb of each hand (dry) as lightly as he could

(b) held the wire in his hand lightly

(c) grasped the wire tightly.

2nd (a) (b) + (c) with wetted hands.

3rd (a) (b) + (c) were repeated with strips of sheet zinc in place of the wires of the last experiment. These strips were 8" long and 1½" wide. The hands dried

4th (a) (b) + (c) with the same strips but the hands wetted.

5th (a) (b) + (c) with the wire in one hand (dry) and standing in boots on the dry plate, itself on the dry floor. Day has been dry though weather humid.

6th (a) (b) + c with the hand wetted.

7th The resistance between the hand immersed in jar of tap water up to the wrist with the above zinc plates as electrodes

8 volts 1000 mm f.2

Set	Holding	Conditions Hands			Lehmann	Hipple	Hayes	Fred.	Batchelor	
						Names				
1	Wires	dry	touching wire		100,000	130,000	200,000	92,000	400,000	
			grasping wire		80,000	36,000	170,000	50,000	200,000	
			clutching "		25,000	25,000	60,000	44,000	70,000	
2		wet	touching "		16,000	30,000	50,000	50,000	40,000	
			grasping "		14,000	13,000	25,000	35,000	16,000	
			clutching "		6,300	9,000	17,000	21,000	13,000	
3	Strips	dry	touching strip		75,000	100,000	160,000	50,000	200,000	
			grasping "		25,000	33,000	77,000	44,000	80,000	
			clutching "		6,000	10,000	37,000	11,700	21,000	
4		wet	touching "		10,000	33,000	55,000	32,000	100,000	
			grasping "		6,000	21,000	30,000	28,000	14,000	
			clutching "		2,700	7,000	16,000	8,000	9,000	
5	Standing on plate with one hand	dry	touching wire		32,000	68,000	110,000	55,000	200,000	
			grasping "		26,000	35,000	100,000	35,000	80,000	
			clutching "		16,000	18,000	49,000	20,000	60,000	
6		wet	touching "			23,000	50,000	32,000	60,000	
			grasping "			22,000	38,000	28,000	40,000	
			clutching "			8,000	16,000	14,000	35,000	
7			Res. of body between hand immersed in plain water.			2550	2700	2250	2650	

The only reasonable assumption appears to be that there were originally 3 circuits on the Bechtelville magnet each 90 lbs of #12 B.S. 0.081" having a res. of 0.08 w per lb = 7.02 w
÷ 3 = 2.4
two circuits above this each of 145 lbs #12 B.W.G 0.109" = 0.024 = 3.145
÷ 2 = 1.74
Total 4.14 w

90 lbs of #12 B.S. @ 50 ft per lb	= 4500 feet.	= 340 turns × 8.67	=	2960 AT
90 " " "	"	"		2960
90 " " "	"	"		2960
145 " " B.W.G. @ 27.8 " "	4060 "	= 308 × 13	=	4000
145 " " "	"	= 205 × 13	=	4000

The Watts generated @ 26 amp = 2860 = 680 therms per sec. 16880 AT
The surface of the magnet is 25.2 sq. ft. = 23400 sq cms.
= 0.129 Watts per sq. cm. = 0.029 therms per sq. cm.
This is excessive. Suppose that there should be not more than 0.014 therms to the sq. cm: = abt 18 amperes in this case.
The new magnet should therefore have say 25000 ampere turns at this surface rate of heat dissipation.
The surface is 7.5 × 1.75' = 13.12 sq ft = 12,200 sq. cms
12200 × 0.014 = 1.22 × 1.4 × 10^2 = 170.7 therms per sec.
= 717 Joules per sec.
= 6.5 amperes.

25000 ÷ 6.5 = 3846 turns = 3846 × 7.5 = 28,840 feet
110 ÷ 6.5 say ÷ 7 = 15.6 w = 1850 feet per w = #10 B.W.G.
1850 × 0.054 = 998 lbs. altogether too expensive.

Taking 20,000 ampere turns and 0.020 therms.
= 2.44 therms per sec
= 1025 Watts
= 9.31 amperes.

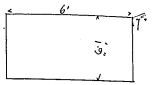
20,000 ÷ 9.31 = 2150 turns = 2150 × 7.5 = 16120 feet
110 ÷ 9.5 = 11.58 w = 1392 feet per w
= #11 B.W.G.
16120 × 0.0436 = 703 lbs. wire.
say 700 lbs of #11 B.W.G.

Check 700 × 0.0164 = 11.48 w @ 110 volts say 12 w = 9.18 amperes.
700 × 22.94 = 16,058 feet ÷ 7.5 = 2140 turns = 19,660 A.T.
110 × 9.18 = 1009.8 say 1010 Watts = 240.6 therms
= 2.406 × 10^2 ÷ 1.22 × 10^4 =
nearly 2.0 × 10^-2 = 0.02 therms per □
= 0.084 Watts per sq. cm.

Allowing 0.1 Watts per cm = 1220 Watts = 11.1 amperes = 10 w.
20,000 ÷ 11.1 = 1800 turns = 13,500 feet = 1350 ft per w = #11 wire 0.4
13500 × 0.0436 = 589 lbs. say 600 lbs of #11 B.W.G.

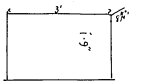
On the winding of an Ore Milling Magnet for Gilbert's mine Bechtelville Pa.

The previous magnet had it is stated 500 lbs. of #13 ? B.W.G. wire. The dimensions were as shown.



One turn would be 13' 2" = 13.17'
= 13.17 × 2.73 × 10^-2 lbs = 0.36 lbs.
so that there would be 500/0.36 = 1390 Turns
say 1400 or 26 × 1400 = 35000 A.T.
140/26 = 4.08 w 500 lbs of #13 = 214 w
#14 = 36

The new magnet is to have the following dimensions so that one turn will have a length of 7.5 feet. The current to be 20 amperes on 120 volts = 6 w.



#13 wire = 4.187 w × 10^-2 per lb
600/4.187

The Ore Milling Magnet at work in the laboratory allows 23 amperes to flow through it from the 110 volt cct or has a res. of 4.78 w at starting = 19.12 w in all. There being two circuits. 23.88 × 19.12 = 456 lbs. of wire.
The current strength is thus 9025/23 = 390 c.m. per ampere.

The ore milling magnet at Bechtelville has it is said 500 lbs of wire on it, to which 126 has lately been added. The current commenced at 26 amp. but fell with time to twenty. Supposing it also to have two cct this would be 13 amp. @ 110 volts = 110/13 = 8.46 w × 2 = 16.92 w in all. 126 lbs have a res. of 4.19 × 1.26 = 5.28 w. If the previous 500 were in 2 cct:
= 4.23 w. 4.23 + 2.64 = 6.87 w. 110/6.87 = 16.0 amperes.

By letter of 27th July from Mr Kreuzi the ore milling magnet at Bechtelville has

1st section of 3 layers	#12 B.S.	27 volts	0.081" = 0.073 w per lb	= 19.71 w
2nd " " 3 "	#12 B.W.G.	29 "	0.109 = 0.024 w "	= 7.02 w
			Phoenix Total res:	26.73 w
3rd " " 2 "	#13 B.W.G.	127	0.095 = 0.0419 "	= 5.32
			Total present res.	32.05 w

at 120 volts 26 amp = 4.23 w.
9.85 × 7.02 / 16.87 = 4.10 7.02 × 19.7 / 26.7 = 5.18 × 26 = 134.7
13.84 ×

The Laboratory ore milling magnet having a surface of about 23,000 sq. cms and taking 23 × 110 = 2530 Watts = 0.11 Watt per sq.

Meter Experiment

by Mr C. West 25th July 1889.

One lamp in cct with a 100 light bottle for 45 mins: Current on lamp 0.34 amp × 1224 × 0.75 = 312 mgms. Actual gain 320 mgms on gain plate 320 and plate not perfectly dried.

Test of New Standard Meter Shunt.

26th July 1889 Friday.

A current from the 5 volt machine was passed through the new standard meter strip and also through the standard legal ohm, whose electrodes were reamalgamated and which stood in a jar of water. The differential method was employed.

The res: of both coils was 5425ω @ 25·3° C T.B.

1st trial 4532ω added to 1ω cct. Temp. of water inside legal ohm 25°

Res: of legal ohm at this temp = 28-15·5 = 12·5 × ·03 = ·375 = 1·00375

2712 + 4532 : 2712 :: 1·00375 : x

$$x = \left(\frac{7244}{1.00375 \times 2712}\right)^{-1} = 0.3758\omega$$

2nd trial 4514ω added to 1ω cct Temp water 23°C

Res of legal ohm = 23 − 15·5 = 7·5 × 0·03 ·225 = 1·00225

2712 + 4514 : 2712 :: 1·00225 : x

$$x = \frac{1.00225 \times 2712}{7226} = 0.3763\omega$$

3rd trial 4509ω added to 1ω cct. Temp. water 23°C

Res: legal ohm = 1·00225

2712 + 4509 : 2712 :: 1·00225 : x

$$x = \frac{1.00225 \times 2712}{7221} = 0.3765$$

4th trial 4509ω added to 1ω cct. Temp water 22°C

Res: legal ohm = 1·00195

2712 + 4509 : 2712 :: 1·00195 : x

$$x = \frac{1.00195 \times 2712}{7221} = 0.3764\omega$$

Temp: of air in meter box 23·3°C.

Res: of both galvo: coils after test 5425ω as before + 4509ω = 4508ω T.B. 3.7

Accepted result of test = 0·3764ω @ 23·3°C.

Taking the electrochemical equivalent of zinc per ampere hour as 1.224 we have 1223 × 0·3764 = 460·3 − 2·3 if res: of bottle be taken as 2·3 leaves 458ω as the res: required in the spool in order that one milligramme transfer shall represent the ampere-hour.

On the Power Required to Decompose 25 gallons of water per min.

One ampère decomposes 9.324×10^{-5} gms per sec:

1 gallon = 8 lbs

25 - " " 200 -

1 lb = 454 gms

200 - = 90800 gms = 9.08×10^{4}

$$\frac{90.80 \times 10^{4}}{9.324} = 9.74 \times 10^{3} \text{ ampères} \div 60 = 1.62 \times 10^{2}$$

$$9.74 \times 10^{3} \times 3 = 28.22 \times 10^{3} \text{ watts.}$$

$$\frac{2822}{746} \times 10^{6} = \frac{3.784}{60} \times 10^{4} \text{ H.P.} = 6.3 \times 10^{4} \text{ HP} = 63000$$

Even allowing only 2 volts as necessary it would still mean 42,000 HP.

In a letter of the 26th January, 1890 a gentleman in Buenos Aires Mr Fr Reynaud, asks Mr Edison how much power would be needed to electrolyze 6000 cubic feet of hydrogen per hour.

6000 c.f. per hr. = 100 c.f. per min = 1.667 c.f. per sec:

1 c.f. = 28316 c.c. ∴ 1.667 c.f. = 47,200 c.c.

11316 c.c. H. weigh 1 gm ∴ 1.667 c.f. of H. weigh 4.170 gms.

4.171 gms of H exist in 9×4.171 = 37.53 g gms. H_2O.

$$\text{Ampère required} = \frac{3.754 \times 10^{1}}{9.324 \times 10^{-5}} = 4.025 \times 10^{5}$$

At 2 volts emf = 8.05×10^{5} Watts

= 805 Kilowatts.

= 1094 chevaux vapeurs.

@ 90% eff = 900 klt or 1210 chevaux vapeurs

A coulomb liberates 1.038×10^{-5} grammes of hydrogen &

1 gm = 11316 c.c.

∴ 1 coulomb liberates $1.038 \times 1.1316 \times 10^{-1}$ = 0.1174 c.c.

∴ 1 ampère develops in one second 0.1174 cc.

" " " " minute 7.044 cc.

" " " " hour 426 cc.

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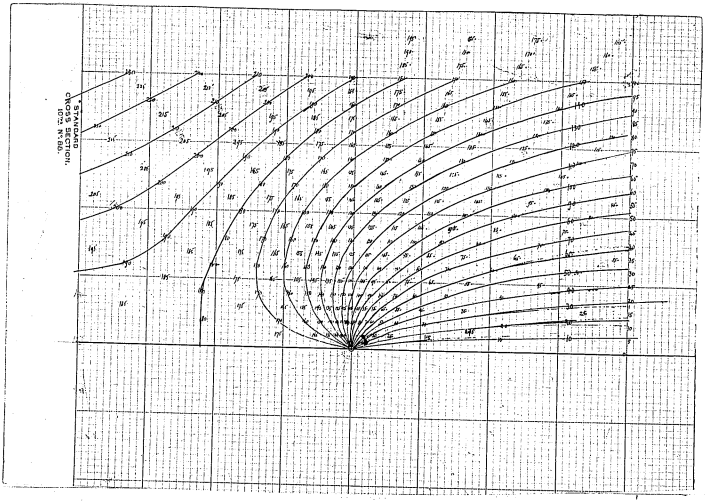

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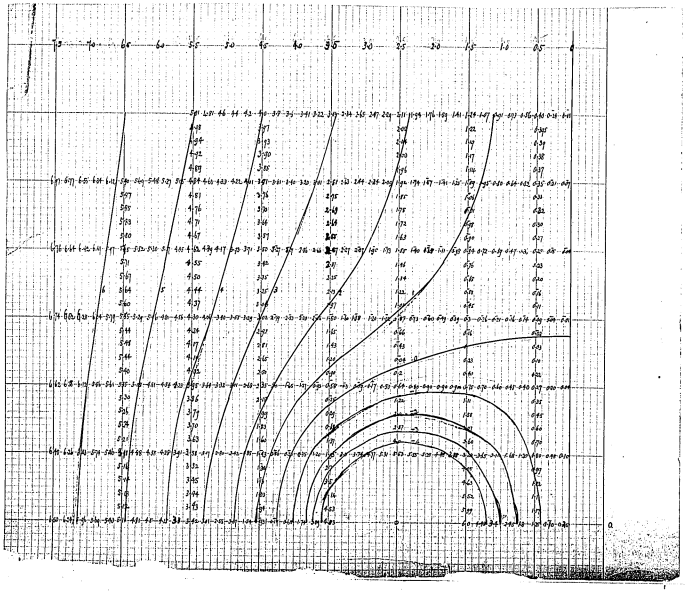

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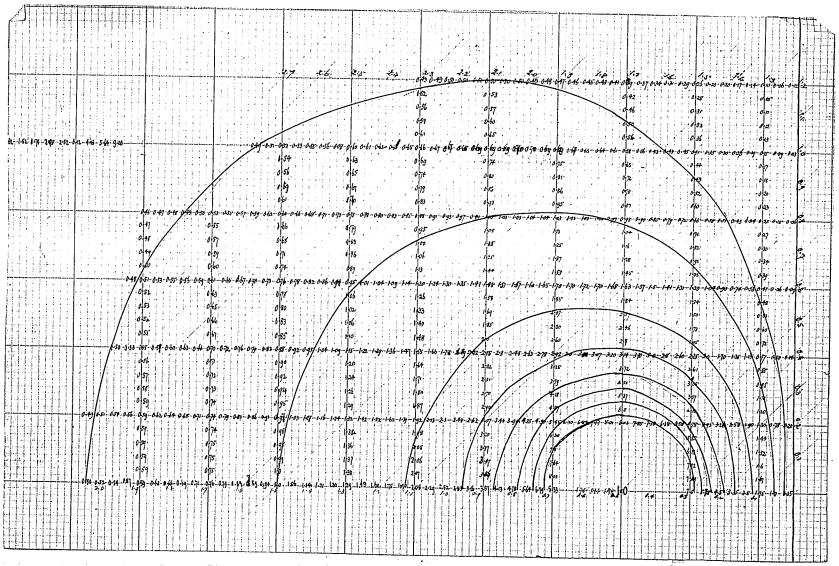

Kennelly Notebook #2

This notebook covers the period July 1889-February 1890. It contains transcriptions by Arthur E. Kennelly of material from the rough record books used by experimenters in the Galvanometer Room. There are notes, drawings, tables, and calculations regarding a variety of electrical experiments, including tests of meters, transformers, induction coils, insulation, and the carrying capacity of various electrical conductors. In addition, there are notes concerning the technical and commercial development of the Niagara hydroelectric power system and tests of motors for the electric railway, phonograph, and sewing machines. Also included are entries pertaining to the electrochemical treatment of arthritic conditions, Kennelly's account of an accidental electric shock he received, and theoretical notes about physics, electricity, and mathematics. Among the experimenters whose work appears in this book are F. P. Bergh, E. C. Boynton, Albert B. Herrick, and Theodore Lehmann. At the end of the book is a subject index (filmed at the beginning of the book). The front cover is marked "II," "1889-1890," and "T." The book contains 165 numbered pages. Some pages were removed before the book was paginated. Graphs and other items have been pasted into the book.

Missing page number: 108.

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Record Book

of

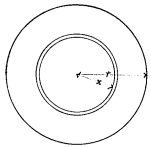
Observations, Calculations, and Data

compiled in the Galvanometer Building

Edison Laboratory Orange N.J.

commenced 28th July 1889
concluded 24th February 1890.

On the Mathematical Theory of the Development of heat in an infinite homogeneous cylindrical conductor freely suspended in air and traversed by a current.



Let r be the radius of the conductor
" ρ " its resistivity at existing temp.
" c " the total passing current.
" J " Joules equivalent 42 megalergs
" K " the thermal conductivity
" D " " density
" σ " " thermal capacity.

Then consider the thermal condition of a corona of unit length and radii x and $x + dx$.

The area of this corona is $2\pi x\,dx$ = also its volume

" current traversing it is $c\,\dfrac{2\pi x\,dx}{\pi r^2} = \dfrac{2cx\,dx}{r^2}$

" resistance of it is $\dfrac{\rho}{2\pi x\,dx}$

" energy developed in it per sec: is $\dfrac{4c^2x^2\,dx^2\,\rho}{2\pi r^4 x\,dx} = \dfrac{2c^2x\,dx}{\pi r^4}$

" heat developed in therms is $\dfrac{2c^2\rho\,x\,dx}{J\pi r^4}$

" flux across the inner surface of the corona is $-2\pi K\dfrac{dv}{dx}x$ per sec

" " " " outer " is $-2\pi(x+dx)K\left(\dfrac{dv}{dx} + dx\dfrac{d^2v}{dx^2}\right)$ per sec

" difference neglecting a quantity of the second order is

$$2\pi Kx\,dx\,\frac{d^2v}{dx^2} + 2\pi K\,dx\,\frac{dv}{dx} = 2\pi Kx\,dx\left(\frac{d^2v}{dx^2} + \frac{1}{x}\frac{dv}{dx}\right)$$

" total rise of heat in the corona per second is thus

$$2\pi Kx\,dx\left(\frac{d^2v}{dx^2} + \frac{1}{x}\frac{dv}{dx}\right) - \frac{2c^2\rho\,x\,dx}{J\pi r^4}$$

" heat required to raise the corona $1^\circ C$ is $2\pi x\,dx\,\sigma D$

so that
$$2\pi Kx\,dx\left(\frac{d^2v}{dx^2} + \frac{1}{x}\frac{dv}{dx}\right) + \frac{2c^2\rho\,x\,dx}{J\pi r^4} = 2\pi x\,dx\,\sigma D\,\frac{dv}{dt}$$

or
$$\frac{dv}{dt} = \frac{K}{\sigma D}\left(\frac{d^2v}{dx^2} + \frac{1}{x}\frac{dv}{dx}\right) + \frac{c^2\rho}{J\pi^2 r^4\sigma D} \quad \ldots\ldots (1)$$

Now since the permanent state is assumed to have been reached, $\dfrac{dv}{dt} = 0$ and consequently

$$\frac{d^2v}{dx^2} + \frac{1}{x}\frac{dv}{dx} = -\frac{c^2\rho}{JK\pi^2 r^4 \sigma D} = -\varphi \text{ suppose} \quad (2)$$

Then
$$x\frac{d^2v}{dx^2} = -\frac{dv}{dx} - \varphi x \quad (3)$$

$$\therefore\ x\frac{dv}{dx} = -\frac{\varphi}{2}x^2 + a \quad (4)$$

$$\therefore\ \frac{dv}{dx} = -\frac{\varphi x}{2} + \frac{a}{x}$$

$$v = -\frac{\varphi}{4}x^2 + a\log x + b \quad (5)$$

When $x = 0$ $v = V$

$$V = a + b \quad (6)$$

" $x = r$ $v = \theta$

$$\theta = -\frac{\varphi r^2}{4} + a\log r + b$$

$$\therefore\ b = \theta + \frac{\varphi r^2}{4} - a\log r \quad (7)$$

by (4) when $x = 0$ $\dfrac{dv}{dx}$ cannot be ∞ $\therefore a = 0$

but if $a = 0$ when $x = 0$ $a = 0$ always

$$\therefore\ \frac{dv}{dx} = -\frac{\varphi x}{2}$$

$$v = -\frac{\varphi x^2}{4} + b$$

when $x = r$ $v = \theta$ $\therefore \theta = -\dfrac{\varphi r^2}{4} + b$ $\therefore b = \theta + \dfrac{\varphi r^2}{4}$

$$\therefore\ v - \theta = \frac{\varphi}{4}(r^2 - x^2)$$

for $x = 0$ $V - \theta = \dfrac{\varphi r^2}{4}$

$$= \frac{c^2\rho}{4JK\pi^2 r^2}$$

$$= \frac{(c)^2}{(\pi r)^2}\,\frac{\rho}{JK}$$

Also when $x = r$ $\quad \frac{dv}{dx} = -\frac{h\theta}{k}$ because $-k\frac{dv}{dx} = h\theta$

$\therefore$ by (4) $\quad -\frac{rh\theta}{k} = -\frac{\rho r^2}{2} + a$

$$\therefore \quad a = \frac{\rho r^2}{2} - \frac{rh\theta}{k} \qquad (8)$$

So that (5) becomes $\quad v = -\frac{\rho}{4}x^2 + \log_e\left(\frac{\rho r^2}{2} - \frac{hr\theta}{k}\right) + \theta + \frac{\rho r^2}{4} - \log_e\left(\frac{\rho r^2}{2} - \frac{hr\theta}{k}\right)$

$$\therefore \quad v - \theta = \log\left(\frac{x}{r}\right)\left(\frac{\rho r^2}{2} - \frac{hr\theta}{k}\right) - (r^2 - x^2)\frac{\rho}{4} \qquad (9)$$

This expression vanishes when $x = r$

When $x = 0$ $\quad (V - \theta) = +\frac{r^2\rho}{4} + \left(\frac{\rho r^2}{2} - \frac{rh\theta}{k}\right)(1 - \log r)$

$$= \frac{c^2\rho}{4J\kappa\pi^2 r^2} + \left(1 - \log r\right)\left(2T - \frac{rh\theta}{k}\right)$$

where T is the 1st term $\left(\frac{c^2\rho}{2}\right)$

When $r = 1$ (conductor nearly 1" in diam)

$c = 1000$ amps $= 100$ in abs.

$\rho = 2000$ abs w. at temp. supposed to be existing.

$J = 4.2 \times 10^7$

$\kappa = 1.1$ for copper

$\pi^2 = 10$

$h = 6.0 \times 10^{-4}$

$\theta = 50$ abs

we have $\quad 3\left(\frac{1.0 \times 10^4 \times 2.0 \times 10^3}{4 \times 4.2 \times 10^7 \times 1.1 \times 1.0 \times 10^1}\right) - \frac{1 \times 6.0 \times 10^{-4} \times 5.0 \times 10^1}{1.1}$

$$= \frac{6 \times 10^7}{19.5 \times 10^8} - \frac{30 \times 10^{-3}}{1.1}$$

$$= 4 \times 10^{-2} - 3 \times 10^{-2}$$

$$\Rightarrow 1 \times 10^{-2}$$

Or the difference of temperature between the axis and surface of such a conductor would not exceed $\frac{1}{100}$th of one degree Centigrade.

In fact consider this conductor to be enveloped by a cylinder of thickness 1 cm whose thermal conductivity is equal to that of copper (1.1) but whose electrical conductivity is zero, and let the outside surface of this cylinder be maintained at 0°C. Then the total heat developed in unit length of the conductor per second equal

$$\frac{1.0 \times 10^4 \times 2.0 \times 10^3}{4.2 \times 10^7 \times 3.14} = 0.152 \times 10^0 = 1.52 \times 10^{-1}$$

The equivalent surface of the envelope would be roughly $2\pi \times 1.5 = 9.42$ cms: and the thickness would be 1

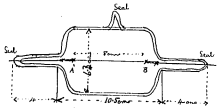
$$\therefore \quad -k\frac{dv}{dx} \times 9.42 = 0.152$$

$$dv = -\frac{0.152}{1.1 \times 9.42} = -0.0147$$

or a little more than $\frac{1}{70}$ of one deg. C

The effect of the augmented distribution and development of heat which varies directly as the radius, is to still further reduce the gradient

Record of test made on the 1st Nov: 88 under my directions by Messrs Bergh + Boynton upon the fusing point of metal wire sealed in exhausted globes.



These globes were blown in the shape indicated that is to say roughly cylindrical. The thickness of the glass varies from 0.015" = 0.038 cm to 0.04" = 0.10 cm but averages about 0.02" = 0.05 cm. in the cylindrical part. The circumference of the cylinder was about 20 cm., and the internal radius consequently about 3.15. Three platinum wires each 0.0125" = 0.032 cm were brought through the seals at the extremities and connected with the wire under test at the points A and B about 8 cm apart. The globes were then exhausted and sealed. A current was then passed through these globes immersed in water contained in a basin and at an observed temperature. The deflection at which luminosity was first reached, and the fusing point were taken. Two globes were prepared for each metal.

Copper wire Diam: 0.0155" = 0.0394 cm.

Res. @ 20°C $= \cancel{\frac{217.5 \times}{275 \times 78.2}} = \cancel{\frac{217.5}{21500}} = \cancel{0.01012}$ " per cm.

$\cancel{= 0.01012 \times 0.0394 =}$

$= \frac{475 \times 0.1}{\cancel{217.5} \times 78.2} = \frac{47.5}{17010} = \frac{1.455}{\cancel{777}} \times 10^{-3}$ " per cm.

$= 1.617 \times 10^{6} \times 1.219 \times 10^{-3} = 1.975 \times 10^{3}$ resistivity at 20°C.

$= 1650$ " 0°C.

Watch deflection at first appearance of luminosity = 1.15 = 5.90 amp.

" platinum red heat 1.24

" cherry " " 1.50

" fusion 1.52 = 7.796 "

At melting point of copper 1054°C = 1328° abs.

by Siemens formula $r_{20} = 0.026577 \times \frac{\sqrt{294}}{\cancel{17.65}} + 0.00311443 \times 294 - 0.29751$

$= 0.4558 + 0.9246 - 0.29751$

$= 1.0829$

$r_{525} = 0.026577 \times \frac{\sqrt{799}}{28.3} + 0.00311443 \times 799 - 0.29751$

$= 0.7518 + 2.512 - 0.2975$

$= 2.9663$

$r_{1054} = 0.026577 \times \frac{\sqrt{1328}}{36.45} + 0.00311443 \times 1328 - 0.29751$

$= 0.9686 + 4.176 - 0.2975$

$= 4.847$

By this reckoning the res: of the wire would be $\frac{1.455 \times 10^{-3} \times 2.9663}{1.0829} = 3.985 \times 10^{-3}$ @ 525°C and $\frac{1.455 \times 10^{-3} \times 4.847}{1.0829} = 6.512 \times 10^{-3}$ @ 1054°C

The energy developed per unit length + time at 525°C was $\frac{5.9^2 \times 3.985 \times 10^{-3}}{4.2} = \frac{3.307}{4.2} = 4.475 \times 10^{-3}$

" " " " " " 1054°C " $\frac{7.8^2 \times 6.512 \times 10^{-3}}{4.2} = \frac{9.45}{4.2} = 2.14 \times 10^{-3}$

" surface of unit length = 3.1416 × 0.0394 = 0.1238

$\therefore x = \frac{0.02207}{500 \times 0.1238} = \frac{3.307 \times 10^{-2}}{6.19 \times 10^{1}} = 0.534 \times 10^{-3} = 5.34 \times 10^{-4}$ for 525°C

$x = \frac{0.0243}{1030 \times 0.1238} = \frac{2.14 \times 10^{-2}}{1.238 \times 1.03 \times 10^{3}} = 0.952 \times 10^{-3} = 9.40 \times 10^{-4}$ for 1054°C.

The second copper wire first became luminous when the Obach deflection was 1·2 and fused when the latter reached 1·5. The temperature of the immersion bath was 21°C. Practically the same results. The following table gives the full particulars

No.	Metal	Diameter in In.	Diameter in Cms.	Inches Area.	Inches Surface	Centimetres Area.	Centimetres Surface	at Commencing Obach	at Commencing Deg. °C	at Commencing Current	at Obach 2·4	at Obach 2·4 Deg. °C	Fusion Current
1	Cu	0·0170	0·0432	0·000227	0·0534	0·00147	0·1360	1·0	21°	5·13	1·30	21°	6·47
2								1·0	21°	5·13	1·32	21°	6·77
3	Ag?	0·0152	0·0386	0·000181	0·0478	0·00117	0·1213	0·90	21°	4·62	0·97	21°	4·98
4											0·97	22°	4·98
5	Cu	0·0155	0·0394	0·000189	0·0487	0·00122	0·1238	1·15	22°	5·90	1·52	22°	7·80
6								1·20	21°	6·16	1·50	21°	7·70
7	Solder	0·0418	0·1062	0·001037	0·1313	0·006689	0·8330				0·93	22°	4·77
8											0·82	21°	4·21
9	Ni	0·0123	0·0312	0·000119	0·0386	0·000760	0·0980	0·31	21°	1·59	0·76	21°	3·90
10								0·52	22°	2·67	0·90	22°	4·62
11	Fe	0·0172	0·0437	0·000232	0·0540	0·00150	0·1373	0·53	23°	2·72	1·34	21·5	6·87
12								0·68	21°	3·49	1·34	21°	6·87
13	Steel	0·0152	0·0386	0·000181	0·0478	0·00117	0·1213	0·42	21·5°	2·15	0·93	21·5	4·77
14								0·47	21·5°	2·41	0·90	21·5	4·62
15	Pt	0·0240	0·0610	0·000452	0·0754	0·00292	0·1916				0·82	19°	4·21
16											0·78	21°	4·00
17	Al	0·0152	0·0386	0·000181	0·0478	0·00117	0·1213	0·88	22°	4·51	0·95	22°	4·87
18								0·87	21°	4·46	1·00	21°	5·13
19	Cd	0·0206	0·0523	0·000333	0·0647	0·00215	0·1643				0·70	22	3·59
20											0·72	20·5	3·60
21	Brass	0·0158	0·0401	0·000196	0·0496	0·00126	0·1260	0·70	19	Gas brought	0·92	19°	4·21
22								0·96	20	4·92			6·57
23	German Silver	0·0172	0·0437	0·000232	0·0540	0·00150	0·1373						
24								1·16	21·5	5·95	1·9		9·75
25	Mg	0·0172	0·0437	0·000232	0·0437	0·00150	0·1373	1·26	21·5	6·46	1·4	21·5	8·72
26								1·66	20·5	8·41	1·85	20·5	9·53

No.	Metal	Length	Deflection	Deflection obs 0·1	Res.	Res per cm.	Resistivity @ temp.	Energy Kg. metres per sec. @ 525°	k @ 525°	k @ fusing temp	fusing temp
1	Cu	6·1	46·2	421·5							
2		6·1	42·4	421·2							
3	Ag?	15·2	1·81	429·2							
4		14·7	1·82·8	239·0							
5	Cu	7·8·2	4·75	417·5	0·1138	$1·455 \times 10^{-3}$	$1·775 \times 10^{-6}$	0·0331	0·0403	0·00053	0·00074
6										0·00224 watt	0·00314 cg
7	Solder	14·8	1·22	419·7						1·186 Watts	3·477 W.B.
8											
9	Ni	6·9	207	390							
10											
11	Fe	14·0	49·35	424·5							
12											
13	Steel	6·2	420	390							
14											
15	Pt	15·0	200	389							
16											
17	Al	40·1	471·5	423·5							
18											
19	Cd	13·8	227·8	423·8							
20											
21	Brass	12·4	487·5	420							
22											
23	German Silver	7·0	480	393							
24											
25	Mg	14·5	393	419·5							

By Preece's tables

Copper wire	0·0155"	would be fused by	20 amps	and were in this case by						7·75
Iron .	0·0172	- - - -	27·5 -	- - - -	- - - -					6·87
Lead .	0·0240	- - - -	8·5 -	- - - -	- - - -					4·20
Aluminium -	0·0172	- - - -	17 -	- - - -	- - - -					5·05
German Silver -	0·0172	- - - -	12·5 -	- - - -	- - - -					9·23

log 1·0077 = 0·0033213 × (525 − 21) = 1·6789752 = log⁻¹ 47·75 − 1 = 46·75
× 0·06858 = 3·0658 = calculated radiation in Watts per sq. cm @ 525°C

= 1·0077 = 0·0033213 × (1054 − 21) = 3·4412329 = log⁻¹ 27·62 − 1 = 2762.
× 0·06858 = 18·106 = calculated radiation in Watts per sq. cm @ 1054°C

Carrying Capacity of Conductors:

A wire of soft copper 0.058" = 0.14732 cms diam (#17 SWG) was suspended somewhat diagonally across the room the length being about 7885 cms. They were fixed about 250 cms above the ground and about 25 cms apart. The Obach galvo. and the grid of full length 0.0499 were included in the circuit. The experiment was arranged for the purpose of ascertaining how far the emissivity was affected by superficial changes on the wire.

Wire #1 was given a slight coating of shellac varnish
" #2 " " solution of Na_2S " copper sulphide by applying
" #3 " " " ~~phosphorus~~ phosphor bronze applied with molasses.
" #4 " brightened by rubbing with emery paper
" #5 left with its usual slightly oxidised surface untouched.

Res. of grid 0.0499

No. of Obs.	Time	Obach	Current	Potente	Current	Mean Potente	Mean Current	Res: of wire at 262.	Mean Res: $\phi\sigma$	Res: per cent. @ 0°C	Resistivity + for cmds
1	11.00	0.215	1.103	0.0325	1.303	0.0287	1.15	0.0851 Ω	0.0773	·9593 x10⁻⁶	1678
2	·10	0.980	5.03	0.1246	4.995	0.1241	4.97		7.73x10⁻²	·9592 x10⁻⁶	
3	·20	2.060 (1)	10.46	0.2614	10.47	0.2611	10.46		7.815 x 10⁻²		
4	·28	3.04 (1)	15.59	0.3960	15.87	0.3974	15.93			Average 1.597 x10⁻⁶	
5	·37	4.04 (1)	20.71	0.5204	20.86	0.5204	20.86				
6	·48	4.68 (1)	24.00	0.6286	25.20	0.6153	24.66				
7	11.00	5.84 (1)	29.95	0.7750	31.06	0.7678	30.77				
8	·14	7.16 (1)	36.72	0.9614	38.54	0.9577	38.39				
9	·20	7.88 (1)	40.41	0.5234	41.96	0.5190	41.61				
10	·37	8.64 (1)	44.31	0.5720	45.87	0.5705	45.74				

0.0280

No. of Obs.	Time	Res: added to wire	Total res. in wire ect.	Res: of wire	$\frac{R}{r}$	Rise of temp. in	Current amperes	Energy per sq. cm.	Emissivity	Temp. air	Res. of 1 cm wire
1	10.55	1940	4650	0.0850	1.00		1.2	1.4648 7.4410⁻⁶		26.1°C.	1.0290x10⁻⁴
2	·55	1950	4660	0.0857	1.001	c.2	5.0	27.07x10⁻⁶ 137.5x10⁻⁶			1.096
3	02 28	2075	4785	0.0881	1.029	7.46	10.5	1.242x10⁻⁶ 6.44x10⁻⁶	8.6 x10⁻⁴		1.127
4	25 27	2260	4975	0.0915	1.069	17.79	15.9	2.85x10⁻⁶ 18.13x10⁻⁶	6.46 x10⁻⁴		1.171
5	31 28	2590	5300	0.0975	1.139	35.8	20.9	5.11x10⁻⁶ 28.9x10⁻⁶	7.45 x10⁻⁴		1.248
6	10.44	2915	5625	0.1035	1.209	53.9	24.7	6.97x10⁻⁶ 41.5x10⁻⁶	7.72 x10⁻⁴		1.324
7	11.00	3400	6100	0.1123	1.312	80.44	30.8	9.36x10⁻⁶ 70.4x10⁻⁶	8.73 x10⁻⁴		1.437
8	·14	4230	6940	0.1277	1.492	126.8	38.4	14.40x10⁻⁶ 127.0x10⁻⁶	9.76 x10⁻⁴		1.634
9	·20	4935	7645	0.1407	1.644	166.0	41.6	31.17x10⁻⁶ 164.4x10⁻⁶	9.68 x10⁻⁴		1.801
10	·37	5500	8210	0.1511	1.766	197.5	45.7	47.79x10⁻⁶ 248.2x10⁻⁶	1.23 x10⁻³		2.26

Shellac

t	Convection assumed for 1 cm.	Total energy per cm	Radiation per cm	Radiation per sq. cm.	Radiation for bright wire	Ratio	Bat. wt	
7.5	0.007	0.0124	0.0054	0.0117	0.00445	2.6	–	
17.8	0.017	0.0216	0.0046	0.00994	0.0102	0.99	–	
35.8	0.038	0.0845	0.0165	0.0356	0.0220	1.62	2	3.24
53.9	0.056	0.1508	0.0248	0.0536	0.0350	1.53	3	4.59
80.4	0.089	0.1363	0.0473	0.1022	0.058	1.76	3	3.52
126.8	0.160	0.2410	0.0510	0.1750			7	11.35
							Mean	1.62

t	Coefficient of convection	Energy per cm	Radiation total	Radiation per sq. cm.	Radiation for a heater two feet long	Ratio radiation/heat	Weight estimated	
1·7	0·102	0·002274	0·00774	0·00159	0·001	1·60	(1)	1·6
8·3	0·108	0·0124	0·00444	0·000508	0·00448	2·98	(2)	3·96
18·3	0·118	0·0245	0·0115	0·02485	0·018	1·91	(3)	5·73
24·2	0·0287	0·05140	0·0253	0·05467	0·017	3·22	(1)	3·22
36·5	0·0366	0·0719	0·0423	0·09114	0·0225	4·05	(1)	4·06
72·4	0·0788	0·1326	0·0538	0·1163	0·051	2·28	(3)	6·84
109·4	0·130	0·2289	0·0959	0·2137	0·087	2·40	(3)	7·20
146·2							14	32·79
							Mean	2·34

t							
2·3	0·0025	0·002274	0·00224	0·00519	0·0013	4·0	
5·8	0·0084	0·01286	0·0039	0·00543	0·0053	1·59	(1) 1·59
18·9	0·0176	0·02945	0·01185	0·0256	0·0113	2·27	(2) 4·54
33·5	0·0332	0·05765	0·02045	0·0442	0·0202	2·19	(3) 6·57
36·9	0·0370	0·05876	0·01976	0·0405	0·0227	1·70	(4) 6·80
70·4	0·0760	0·1322	0·0552	0·1193	0·0447	2·40	(3) 7·20
100·8	0·1170	0·2229	0·1059	0·229	0·0580		13 26·40
134·6							2·05

t	rad. coeff.	Total radiation	Total Energy	Convection
4·1	0·0025	0·001156	0·00276	0·00160
10·6	0·0062	0·00287	0·01253	0·00966
24·5	0·0145	0·00674	0·03036	0·02335
41·5	0·0240	0·0344	0·05761	0·04417
59·8	0·0342	0·0186	0·08462	0·06392
93·6	0·0725	0·0338	0·14090	0·10690

t	rad. coeff.	Total radiation	Total Energy	Convection
4·2	0·0025	0·00116	0·00276	0·00160
11·9	0·0071	0·00329	0·01252	0·00923
25	0·0150	0·006934	0·03011	0·02317
43	0·0270	0·0125	0·05534	0·04288
61·8	0·0425	0·0197	0·08216	0·06246
94·9	0·073	0·0338	0·1410	0·1072

No.	Res. in cat. with wire	Total res. in wire cat.	Res. of wire	$\frac{R}{T}$	Rise of temp.	Current amperes	Res. per cm.	Energy per cm.	Energy per sq. cm.	Thermal per sq. cm.	Emissivity	Temp. cm.	
						C	C^2						
1	1920	4620	0·08525	1·0				1·091 x 10⁻⁶					36·6
2	1950	4660	0·0858	1·0065	1·7	5·0	25	1·098		2·746 x10⁻³	1·415 x10⁻³	8·30 x10⁻³	
3	2070	4780	0·0880	1·032	8·25	10·5	110·3	1·126		1·242 x10⁻²	6·402 x10⁻³	7·76 x10⁻³	
4	2247	4957	0·0913	1·071	18·3	15·9	252·8	1·168		2·952 x10⁻²	1·522 x10⁻²	8·32 x10⁻³	
5	2540	5250	0·0967	1·134	29·2	20·9	436·3	1·237		5·403 x10⁻²	2·786 x10⁻²	9·54 x10⁻³	
6	2775	5485	0·1010	1·185	36·5	24·7	610·1	1·293		7·896 x10⁻²	4·068 x10⁻²	1·33 x10⁻²	
7	3220	5930	0·1092	1·281	72·4	30·8	948·6	1·398		1·326 x10⁻¹	6·836 x10⁻²	9·44 x10⁻³	
8	3880	6590	0·1213	1·423	109·	38·4	1475	1·552		2·289 x10⁻¹	1·180 x10⁻¹	1·08 x10⁻²	
9	4585	7295	0·1343	1·575	148·2	41·6	1731	1·718		2·973 x10⁻¹	1·532 x10⁻¹	1·035 x10⁻²	
10	5120	7840	0·1444	1·690	177·8	45·7	2088	1·888		3·839 x10⁻¹	1·979 x10⁻¹	1·076 x10⁻²	

No.	Res. in cat. with wire	Total res. in wire cat.	Res. of wire.	$\frac{R}{T}$	Rise of temp.	Current amperes	Res. per cm.	Energy per cm.	Energy per sq. cm.	Thermal per sq. cm.	Emissivity	Temp. cm.	
						C	C^2						
1	1900	4610	0·08488	1·0				1·096 x10⁻⁶					34·6
2	1940	4650	0·08562	1·0091	2·3	5·0	25	1·096		2·761 x10⁻³	1·413 x10⁻³	6·17 x10⁻³	
3	2057	4767	0·08778	1·0341	8·8	10·5	110·3	1·123		1·239 x10⁻²	6·381 x10⁻³	7·25	
4	2235	4945	0·09106	1·073	18·8	15·9	252·8	1·165		2·945 x10⁻²	1·518 x10⁻²	8·04	
5	2500	5210	0·09594	1·130	33·5	20·9	436·8	1·228		5·365 x10⁻²	2·746 x10⁻²	8·26	
6	2760	5270	0·09702	1·143	36·9	24·7	610·1	1·242		7·896 x10⁻²	4·068 x10⁻²	1·058 x10⁻²	
7	3160	5870	0·1081	1·273	70·36	30·8	948·6	1·383		1·312 x10⁻¹	6·762 x10⁻²	9·61 x10⁻³	
8	3740	6450	0·1181	1·391	100·8	38·4	1475	1·511		2·229 x10⁻¹	1·149 x10⁻¹	1·114 x10⁻²	
9	4215	6925	0·1275	1·502	129·4	41·6	1731	1·632		2·825 x10⁻¹	1·456 x10⁻¹	1·136 x10⁻²	
10	4710	7420	0·1366	1·610	157·2	45·7	2088	1·749		3·650 x10⁻¹	1·882 x10⁻¹	1·197 x10⁻²	

No.	Res. in cat. with wire	Total res. in wire cat.	Res. of wire	$\frac{R}{T}$	Rise of temp.	Current amperes	Res. per cm.	Energy per cm.	Energy per sq. cm.	Thermal per sq. cm.	Emissivity	Temp. cm.	
						C	C^2						
1	1900	4610	0·08488	1·0				1·086 x10⁻⁶					26·6
2	1977	4685	0·08626	1·0160	4·1	5·0	25	1·104		2·760 x10⁻³	1·423 x10⁻³	3·97 x10⁻³	
3	2115	4825	0·08884	1·041	10·6	10·5	110·3	1·137		1·253 x10⁻²	6·459 x10⁻³	6·49	
4	2335	5045	0·09292	1·095	24·5	15·9	252·8	1·189		3·006 x10⁻²	1·549 x10⁻²	6·32	
5	2645	5355	0·09860	1·161	41·5	20·9	436·8	1·262		5·511 x10⁻²	2·841 x10⁻²	6·84	
6	2970	5680	0·1046	1·232	59·8	24·7	610·1	1·338		8·162 x10⁻²	4·208 x10⁻²	7·04	
7	3575	6285	0·1157	1·363	93·6	30·8	948·6	1·480		1·404 x10⁻¹	7·238 x10⁻²	7·73	
8	4400	7110	0·1309	1·542	139·7	38·4	1475	1·675		2·147 x10⁻¹	1·273 x10⁻¹	9·11	
9	5120	7820	0·1442	1·699	180·1	41·6	1731	1·845		3·194 x10⁻¹	1·646 x10⁻¹	9·24	
10	5670	8380	0·1543	1·818	210·8	45·7	2088	1·974		4·122 x10⁻¹	2·125 x10⁻¹	1·005 x10⁻²	

No.	Res. in cat. with wire	Total res. in wire cat.	Res. of wire	$\frac{R}{T}$	Rise of temp.	Current amperes	Res. per cm.	Energy per cm.	Energy per sq. cm.	Thermal per sq. cm.	Emissivity	Temp. cm.	
						C	C^2						
1	1900	4610	0·08488	1·0				1·086 x10⁻⁶					26·2
2	1977	4687	0·0863	1·0164	4·2	5·0	25	1·104		2·760 x10⁻³	1·423 x10⁻³	3·39 x10⁻³	
3	2110	4820	0·0888	1·046	11·85	10·5	110·3	1·136		1·252 x10⁻²	6·453 x10⁻³	5·45	
4	2345	5055	0·0931	1·097	25·	15·9	252·8	1·191		3·011 x10⁻²	1·552 x10⁻²	6·23	
5	2675	5385	0·0991	1·167	43·	20·9	436·8	1·268		5·538 x10⁻²	2·855 x10⁻²	6·64	
6	3000	5710	0·1052	1·2260	61·8	24·7	610·1	1·347		8·216 x10⁻²	4·235 x10⁻²	6·85	
7	3600	6310	0·1162	1·368	94·8	30·8	948·6	1·487		1·410 x10⁻¹	7·268 x10⁻²	7·67	
8	4625	7355	0·1355	1·596	153·6	38·4	1475	1·734		2·555 x10⁻¹	1·318 x10⁻¹	8·58	
9	5220	7930	0·1460	1·720	185·6	41·6	1731	1·868		3·233 x10⁻¹	1·666 x10⁻¹	8·94	
10	5750	8460	0·1558	1·835	215·2	45·7	2088	1·993		4·162 x10⁻¹	2·145 x10⁻¹	9·97	

Inductance of the large Solenoid of ~~sixteen~~ fifteen layers covered wire.

No. of obs	Date	Section	Observed Res.	Ratio	Capacity on 1000/1000 side	Inductance Secohm	Inductance Kilometer	Mean value Kilometer	Res. of Coil.	Resistance @ 25°C
1	27.7.89	T – II	1.407 ω	1000/10	1.40 f	0.001969	19.69 ω		0.120 ω	
2		II – IV	4.342		1.39 f	0.001865	18.65			
3		T – IV	2.635		2.68 f	0.007062	70.62 ω			
4		T – VI	3.797		3.918	0.014888	148.8 ω			
5		T – VIII	4.905		5.0	0.024553	245.3 ω			
6	29.7.89	T – II	1.421		1.410	0.002003	20.3 ω	20.0		1.304 ω
7		T – IV	2.664		2.640	0.007034	70.34 ω	70.43		2.544 ω
8		T – VI	3.835		3.855	0.014878	147.8 ω	148.3		3.715 ω
9		T – VIII	4.945		4.950	0.024548	244.8 ω	245.0		4.825 ω
10		T – XIII	~~4.867~~	1000/100	0.50	0.024344	243.4			
11		T – X	5.89	-	0.60	0.035334	353.4	353.4 #		5.77 ω
12		T – XII	6.847	-	0.68	0.046657	465.7	465.7		6.73 ω
13		T – XVI	8.647	-	0.820	0.070290	709.0	709		8.53 ω

* The last three measurement are not very accurate.

Comparison of resistances.

July 31st Wednesday

Took a rough comparison of the grid in multiple arc with the 0.01ω standard copy @ 25.5°C. = 0.009675 at that temp. by account.

610ω added to grid.

$$\frac{2730}{3340\,\omega} : 2730 :: 0.01 : 0.009675$$

$x = 0.011184\,\omega$. By account it is $0.0121\,\omega$

Resistance and Inductance of the Speaking Mirror Galvanometer

July 29th Monday.

Resistance of all three coils in series 2.237ω @ 26.5°C. T.R. 27.5°C. 1000/100 added 0.585 f to ratio coil with secohmmeter in order to obtain balance.

$$0.585 \times 10^{-6} \times 1.0 \times 10^{3} \times 2.237 \times 10^{3} = 1.308\,\omega$$
$$= 13{,}080 \text{ kilometers.}$$

t	$(1\cdot0077)^t$	0·05405(1·0077)^t	$(1\cdot0077^t - 1)$	Radiation from sq. cm.	Total radiation Watts	Total correct Watts	t log 1·0077
							~~0·02414537~~
6·44	$(1\cdot0077)^{\frac{1}{2}}$	0·06726	0·0506	0·034·03 $\times 10^{-4}$	0·01739	—	0·02414537
8·76	1·1957		0·0695	0·046775	0·02389	0·013349	0·0291822
11·34			0·09009	0·061114	0·03125	0·02015	0·0377769
15·46			0·1259	0·084688	0·04328	0·02002	0·0515819
18·8			0·1553	0·104445	0·05337	0·0281	0·0626236
30·14			0·2601	0·174894	0·08938	1·01421	0·1090054
52·04			0·4906	0·32998	0·1686	0·0760	0·1735565
62·96			0·6196	0·416774	0·2130	0·0852	0·2094055
83·22			0·89934	0·60090	0·3071	0·10974	0·2772308
102·6			1·1968	0·80497	0·4113	0·1113	0·3147914

(8)

Carrying Capacity of Conductors.

July 26th 1899 Tuesday.

Five strips of bright brush copper were suspended across the galvanometer room about 250 cms from the floor and about 24 cms apart. These strips were prepared as follows:-

No. of strip	Length cms	Breadth	Thickness	Surface per sq. cm	Area sq. cms	Equivalent diameter of equal area cms	Equivalent diameter of equal C. section	Nature of applied to wire
I	591	2·514	~~0·0775~~ 0·0165	5·11	~~0·00595~~ 0·014194	0·239	1·63	Superficial coating. Bright copper, untouched.
II	594·5	1·1"	~~0·0750~~ 0·0065"	2·01 sq. in	~~0·0375~~ 0·0065"	0·0946" 0·091"	0·61"	Varnish with lampblack + shellac and black adhesive varnish
III	591							Brown shellac varnish. Fairly thick coating.
IV	588·3				Equivalent C.M. 9250			B.W.S. thin layer produced by painting with No. 8 adhesive varnish
V	586							Lampblacked by smoking under flame

A photograph was taken by Mr Dixon of the entire arrangement. The temp. of the air was taken by means of a thermometer suspended beneath the strips. Both in this and the preceding experiment the air was kept as still as possible in the room by keeping the doors and windows closed.

The gas flow used in multiple gives 0·01210. The elec. res. of the galv. was 2730 ohms.

1899

No. of Obs.	Time	Long Resp. amplitude	Amplitude	Potentiometer amplitude	Amplitude	Mean Potentiometer Res.	Mean amplitude	Mean res. of wire @ 23·3°C.	Mean res. of wire @ 0°C.	Resistivity and % cons.
1	4.23	–		0·0180	2·975					
2	4.8	–		0·0460	7·602	0·04149	7·304	~~0·02085~~	~~0·02036~~	~~1·663~~
3	15.20/30	0·75 a 1	12·7	0·0769	12·71	0·0751	12·41	0·02293 ω	0·02347 ω	1666
4	15.36/50	1·05	17.	0·1096	18·11	0·10144	17·26			97·2%
5	16.55/17·10	2·90	24	0·1545	25·53	0·1551	25·63			
6	17.53/18·10	3·50	27	0·1750	28·92	0·1738	29·73			
7	18.15/30	4·2	31	0·2025	33·47	0·2024	33·46			
8	26/38	4·85	34·5	0·2208	36·50	0·2230	36·86			
9	34/45	5·7	39·5	0·2500	41·32	0·2517	41·61			
10	40/55	6·9	48·5	0·3114	51·47	0·3134	51·80			
11	46/19.04	8·8	61·5	0·4180	69·08	0·4118	68·06			
12	52/24	9·4	70·5	0·4479	74·02	0·4469	73·86			
13	35/35	10·5	82	0·5150	85·12	0·5126	84·72			
14	45/50	11·25	90	0·5600	92·56	0·5596	92·32			
15	49/20.05	–								
16										

No. of Obs.	Time	Res. added to wire	Total res. in wire at 27°	Res. of wire	$\frac{R}{T}$	Rise of temp. above C.	Current amperes C.	Current amperes C°.	Res. per cm.	Energy per sq. cm. Watts.	Emissivity
1	15.20	3120	5850	0·02593							
2	15.20/30	3180	5910	0·02662	1·010	2·58	12·65	13·8	4·4232 $\times 10^{-5}$	(3818 $\times 10^{-4}$) 3·1770	1·23 $\times 10^{-12}$
3	15.36/50	3265	5995	0·02687	1·0250	6·44	17·3	29·3	4·4495	(3865 $\times 10^{-4}$) 6·71	9·74 $\times 10^{-12}$
4	16.55/17·10	3320	6050	0·02862	1·0344	8·76	20·7	32·7	4·5387	(3788 $\times 10^{-4}$) 1·7620	1·99 $\times 10^{-12}$
5	17.53/18·10	3380	6110	0·02708	1·0144	11·34	23·5	37·2	4·5822	5·1420 $\times 10^{-4}$ 2·35	2·11
6	18.15/30	3470	6200	0·02748	1·060	15·46	26·9	42·6	4·6350	6·33 $\times 10^{-4}$ 2·969	1·91
7	26/38	3545	6275	0·02792	1·073	18·91	29·6	47·31	4·706	8·15 $\times 10^{-4}$ 3·77	2·02
8	34/45	3805	6535	0·02897	1·117	30·14	32·9	52·63	4·901	1·3595 $\times 10^{-3}$ 6·26	2·03
9	40/55	4300	7030	0·03116	1·202	52·04	38·1	60·89	5·273	2·1465 $\times 10^{-3}$ 1·1600	2·19
10	46/19.04	4550	7280	0·03227	1·244	62·96	39·9	64·61	5·4600	2·9215 $\times 10^{-3}$ 1·389	2·21
11	52/24	5010	7740	0·03431	1·323	83·22	44·7	71·74	5·805	4·1650 $\times 10^{-3}$ 1·941	2·33
12	35/35	5450	8180	0·03626	1·399	102·6	48·5	82·19	6·134	5·2262 $\times 10^{-3}$ 2·435	2·37
13		2970	5700	~~0·02525~~							

Temp elevation °C	Rate per min Albumen corrected	Energy per cm²	Total Radiation	Radiation per sq cm	Radiation of triple wire	Ratio	Wt	Total energy
3.1	0.003	0.0132	0.0102	0.0020	0.0021			
4.6	0.0075	0.0347	0.0297	0.00581	0.0023	2.52	1	2.52
6.4	0.011	0.0502	0.0392	0.00767	0.0275	2.79	1	2.79
8.8	0.015	0.0615	0.0455	0.00890	0.0252	1.71	1	1.71
10.5	0.018	0.0748	0.0608	0.0119	0.0062	1.83	2	3.66
17.8	0.029	0.125	0.096	0.0188	0.010	1.88	2	3.76
24.4	0.046	0.226	0.180	0.0352	0.018	1.96	2	3.92
26.3	0.056	0.272	0.216	0.0423	0.023	1.84	3	5.52
46.1	0.067	0.370	0.303	0.0593	0.029	2.04	3	6.12
54.9	0.076	0.452	0.376	0.0736	0.0363	2.10	3	6.30
							18	36.30
							Mean =	2.02
4.4	0.007	0.0132	0.0062	0.00121	0.0025			
5.4	0.0096	0.0362	0.0266	0.00521	0.003	1.74	1	1.74
6.7	0.012	0.0501	0.0381	0.00746	0.0043	1.74	1	1.74
9.0	0.015	0.0613	0.0463	0.00906	0.0053	1.71	2	3.42
11.6	0.019	0.0787	0.0597	0.01168	0.007	1.67	2	3.34
17.8	0.029	0.1247	0.0957	0.01873	0.0103	1.82	3	5.46
31.2	0.038	0.2262	0.1882	0.0368	0.0195	1.89	3	5.67
37.1	0.056	0.2719	0.2159	0.0423	0.023	1.84	3	5.52
46.6	0.068	0.3686	0.3006	0.0588	0.0295	1.99	3	5.97
56.2	0.078	0.4514	0.3734	0.0731	0.0375	1.95	3	5.85
							21	38.71
							Mean =	1.84
5.7	0.008	0.0361	0.0283	0.00515	0.003			
8.0	0.013	0.0496	0.0366	0.00716	0.0047	1.52	(1)	1.52
10.3	0.017	0.0608	0.0438	0.00857	0.006	1.43	(1)	1.43
13.7	0.022	0.0728	0.0508	0.00994	0.0075	1.33	(1)	1.33
20.6	0.033	0.1244	0.0914	0.0179	0.0125	1.43	(2)	2.86
35.0	0.053	0.2261	0.1731	0.0339	0.022	1.54	(2)	3.08
42.3	0.063	0.2727	0.2097	0.0410	0.027	1.52	(2)	3.04
53.9	0.076	0.3722	0.2962	0.0580	0.0355	1.63	(4)	6.52
65.2	0.086	0.4583	0.3723	0.0729	0.045	1.62	(4)	6.48
							18	27.78
							Mean	1.54
4.1	0.0065	0.0131	0.0066	0.00129	0.0023			
6.2	0.010	0.0363	0.0263	0.00515	0.0037	1.39	(1)	1.39
8.5	0.014	0.0498	0.0358	0.00701	0.0047	1.49	(1)	1.49
11.6	0.019	0.0612	0.0422	0.00826	0.0065	1.27	(1)	1.27
14.7	0.025	0.0786	0.0536	0.0105	0.0085	1.24	(2)	2.48
22.4	0.036	0.1253	0.0893	0.0175	0.0135	1.30	(2)	2.60
37.1	0.056	0.2279	0.1719	0.0336	0.0230	1.46	(3)	4.38
45.4	0.066	0.2759	0.2099	0.0411	0.029	1.42	(4)	5.68
58.5	0.080	0.3784	0.2924	0.0574	0.0395	1.48	(4)	5.92
69.1	0.089	0.46644	0.37574	0.0735	0.0482	1.53	(4)	6.12
							22	31.33
							Mean	1.42

No. of obs.	Rec. added to ship	Total rec'd ship cat.	Rec. of ship	R/r	Rise of temp. above	Current amperes C	C'	Rec. per cm	Energy per cm	Thermo per sq. cm	Emissivity
1	3130	5860	0.02597					4.367 $\times 10^{-4}$			
2	3160	5890	0.02611	1.005	1.24	17.3	299.3	4.391	6.752 $\times 10^{-3}$	3.146 $\times 10^{-4}$	2.146 $\times 10^{-4}$
3	3200	5930	0.02625	1.012	3.09	20.7	823.7	4.420	1.323 $\times 10^{-2}$	6.164	2.00
4	3240	5970	0.02646	1.018	4.64	33.5	1122	4.450	3.666	1.708 $\times 10^{-3}$	1.68
5	3280	6010	0.02664	1.025	6.44	34.9	1362	4.480	5.018	2.338	1.63
6	3330	6060	0.02686	1.034	8.76	41.6	1731	4.517	6.152	2.866	2.27
7	3380	6110	0.02708	1.042	10.82	51.1	2223	4.553	7.892	3.673	3.40
8	3435	6265	0.02777	1.069	17.75	68.1	4638	4.670	1.253 $\times 10^{-1}$	5.836	3.26
9	3800	6630	0.02935	1.114	23.38	73.9	5461	4.870	2.259	1.051 $\times 10^{-2}$	3.58
10	3965	6685	0.02963	1.111	36.33	84.7	7174	4.923	3.721 $\times$	1.268	3.49
11	4180	6910	0.03063	1.179	46.12	92.3	8519	5.151	3.664	1.722	3.73
12	4380	7110	0.03152	1.213	56.88			5.301	4.577	2.105	3.84
13	2000	5720									
14											

Lampblack, Gillette — 23.5°

No. of obs.	Rec. added to ship	Total rec'd ship cat.	Rec. of ship	R/r	Rise of temp. above	Current amperes C	C'	Rec. per cm	Energy per cm	Thermo per sq. cm	Emissivity
1	2070	5800	0.02571					4.350 $\times 10^{-4}$			
2	3105	5835	0.02586	1.006	1.55	12.4	153.8	4.375	6.723 $\times 10^{-3}$	3.135 $\times 10^{-4}$	2.02 $\times 10^{-4}$
3	3170	5900	0.02615	1.017	4.38	17.3	299.3	4.424	1.324 $\times 10^{-2}$	6.168	1.44
4	3240	5970	0.02644	1.021	5.41	20.7	423.7	4.440	3.624	1.689 $\times 10^{-3}$	3.12
5	3220	5950	0.02637	1.026	6.70	33.5	1122	4.462	5.007	2.333	3.48
6	3275	6005	0.02663	1.035	9.02	34.9	1362	4.504	6.134	2.858	3.17
7	3330	6060	0.02686	1.045	11.60	41.6	1731	4.534	7.866	3.665	3.16
8	3470	6200	0.02748	1.069	17.78	51.8	2683	4.649	1.247 $\times 10^{-2}$	5.810	3.27
9	3770	6500	0.02882	1.121	31.18	68.1	4638	4.777	2.262	1.054 $\times 10^{-2}$	3.32
10	3910	6640	0.02943	1.144	37.10	73.9	5461	4.879	2.719	1.267	3.58
11	4125	6855	0.03038	1.181	46.63	84.7	7174	5.049	3.698	1.717	3.68
12	4335	7065	0.03131	1.218	56.18	92.3	8519	5.297	4.5114	2.103	3.74
13	2970	5700									

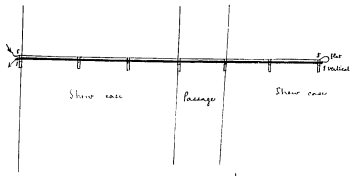
Bronze Gillette — 23.5°

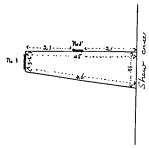
No. of obs.	Rec. added to ship	Total rec'd ship cat.	Rec. of ship	R/r	Rise of temp. above	Current amperes C	C'	Rec. per cm	Energy per cm	Thermo per sq. cm	Emissivity
1	2965	5695	0.02525					4.291 $\times 10^{-4}$			
2	2990	5720	0.02535	1.004	1.03	12.4	153.8	4.307	6.624 $\times 10^{-3}$	3.086 $\times 10^{-4}$	2.00 $\times 10^{-4}$
3	3040	5770	0.02557	1.013	3.35	17.3	299.3	4.347	1.307 $\times 10^{-2}$	6.061	1.81
4	3090	5820	0.02580	1.022	5.67	28.7	823.7	4.384	3.611	1.683 $\times 10^{-3}$	2.97
5	3140	5870	0.02602	1.031	7.99	33.5	1122	4.422	4.961	2.311	2.89
6	3200	5930	0.02628	1.040	10.31	34.9	1362	4.466	6.083	2.834	2.75
7	3270	6000	0.02660	1.053	13.66	41.6	1731	4.521	7.824	3.646	2.67
8	3425	6155	0.02728	1.080	20.62	51.8	2683	4.636	1.2144 $\times 10^{-2}$	5.796	2.81
9	3740	6470	0.02868	1.136	35.04	68.1	4638	4.875	2.261	1.054 $\times 10^{-2}$	3.01
10	3900	6630	0.02939	1.164	42.26	73.9	5461	4.994	2.727	1.271	3.01
11	4155	6885	0.03052	1.209	53.85	84.7	7174	5.187	3.722	1.734	3.22
12	4410	7140	0.03165	1.253	65.18	92.3	8519	5.378	4.583	2.135	3.38
13	2850	5580									

Cu — 23.3°

No. of obs.	Rec. added to ship	Total rec'd ship cat.	Rec. of ship	R/r	Rise of temp. above	Current amperes C	C'	Rec. per cm	Energy per cm	Thermo per sq. cm	Emissivity
1	2950	5680	0.02518					4.296 $\times 10^{-4}$			
2	2985	5715	0.02534	1.006	1.55	12.4	153.8	4.324	6.650 $\times 10^{-3}$	3.098 $\times 10^{-4}$	2.00 $\times 10^{-4}$
3	3045	5775	0.02560	1.016	4.12	17.3	299.3	4.367	1.307 $\times 10^{-2}$	6.089	1.48
4	3090	5820	0.02580	1.024	6.18	28.7	823.7	4.402	3.626	1.689 $\times 10^{-3}$	2.73
5	3140	5870	0.02602	1.033	8.50	33.5	1122	4.440	4.981	2.321	2.73
6	3205	5935	0.02631	1.045	11.60	34.9	1362	4.490	6.115	2.849	2.46
7	3275	6005	0.02662	1.057	14.69	41.6	1731	4.541	7.862	3.663	2.49
8	3445	6175	0.02737	1.087	22.42	51.8	2683	4.670	1.253 $\times 10^{-2}$	5.838	2.61
9	3770	6500	0.02881	1.144	37.10	68.1	4638	4.915	2.279	1.062 $\times 10^{-2}$	2.86
10	3950	6680	0.02961	1.176	45.35	73.9	5461	5.023	2.759	1.286	2.83
11	4245	6975	0.03091	1.227	58.50	84.7	7174	5.214	3.784	1.763	2.81
12	4475	7205	0.03194	1.268	69.06	92.3	8519	5.450	4.644	2.164	3.13
13	2850	5580									

Gentle Graphite — 23.3°





Carrying Capacity of Conductors.

August 1st Thursday.

Finding the emissivity of these strips to be so low, made a special experiment to ascertain the effect of position upon their radiation and convection, for the strips in yesterday's tests were suspended flat but lay over somewhat in the centre of the span and it was thought that if they had been suspended with the plane of the strips vertical the convection might have been greatly facilitated.

Two strips nos (1) + (5) of yesterday, the latter washed and rubbed down with emery paper were fixed upon frames screwed to the show cases. These frames were about one metre apart. On the top rested no. 5 drawn flat. It was about 215 cms above ground and about 25 ft the show cases. At the ends of the frames no 1 was nailed so as to be about 213 cms above ground 21 cms from no 5 and 45 from the show cases, the arrangement being represented by the sketch on the opposite page. A photograph was also obtained.

Grid in multiple arc = 0·0121 ω. Res. of galv 2710 ω per coil. After taking the first set with about 5 and 100 amperes, the strips were exchanged, no 5 being made vertical and no 1 horizontal, no other alteration being made. The test was then repeated. Length of no 1 reduced 7·5

No of Obs.	Time	L.R. Amm. Rdg	Amperes	Potentio Rdg.	Amperes	Mean Potentio Rdg	Mean amperes	Res. of strip per cm @ 26°	Res. of strip @ 0°C per cm	Resistivity compared to Cu	Temp. air
1	11h 11m 50s	0	8	0·0310	5·125	0·0310	5·125				
2	·52 15·00	11·2	89	0·6109	101·0	0·6126	101·3	$4·296 \times 10^{-5}$	$3·902 \times 10^{-5}$	1636 99%	26C

No of Obs. No 1	Res. in cct with strip	Total res. of strip cct	Res. of strip	$\frac{R}{r}$	Rise of temp. above air	Current amperes C. C²	Rise per cm	Energy per cm.	Therms per sq. cm.	Emissivity.
1	2940	5650	0·02523				$4·324 \times 10^{-5}$			
2	5190 (mean of 5 reading)	7400 (mean of 5 reading)	0·03327	1·398	102·6°	101·0 10201	$6·044 \times 10^{-5}$	0·6165	$2·873 \times 10^{-5}$	$2·80 \times 10^{-5}$

No of Obs. No 5	Res. in cct with strip	Total res of strip cct	Res. of strip	$\frac{R}{r}$	Rise of temp. above air	Current C C²	Rise per cm	Energy per cm.	Therms per sq. cm.	Emissivity.
1	2890	5600	0·02501				$4·247 \times 10^{-5}$			
2	5895 (mean of 5 reading)	8205 (mean of 5 reading)	0·03664	1·465	119·8°	101·0 10201	$6·251 \times 10^{-5}$	$6·376 \times 10^{-5}$	$2·971 \times 10^{-5}$	$2·48 \times 10^{-5}$

No of Strip	Position	Length	Breadth	Thickness	Area	Amperes per cm		Emissivity of Platinum strip @ 100°C	Emissivity of upright strip @ 100C	% of vacuum of emissivity
1	Vertical	5993·5	2·54	0·0165	0·04194	5·81		$2·4 \times 10^{-5}$	$2·8 \times 10^{-5}$	17%
5	Horizontal	5986	2·54	0·0165	0·04194	5·11				

To confirm these results repeated them as follows:- with strips exchanged. All the readings were repeated several times to obtain a fair mean value.

Temp	1.0077^t	0.06625(1.077)	$t \lg 1.0077$	$(1.0077^t - 1)$	Radiation per sq. cm	Total Radiation	Total Radiation + Convection	Total convection
120.2		0.68666	0.4010885	1.5182	0.1042	0.5323	0.6337	0.1014
85.8		1.428	0.2858285	0.9312	0.0639 11	0.3268	0.3808	0.0540
46.4			0.1545723	0.4275	0.02935	0.1500	0.1898	0.0398
18.9			0.0626284	0.1551	0.010649	0.0544	0.0632	0.0088
1.55			0.0051635 2	0.0126	0.0008824			
101.3			0.3374667	1.1750	0.08068	0.4123	0.5955	0.1832
71.9			0.2395205	0.7360	0.05053	0.2582	0.3605	0.1023
40.2			0.1393183	0.3612	0.02480	0.1267	0.1836	0.0569
16.75			0.0557937	0.1371	0.009413	0.0481	0.0619	0.0138
1.42			0.0047304	0.0110	0.000755			

Carrying Capacity of Conductors contd.

No. of Obs.	Time	L.R. Amm. reading	Amperes	Potentio Meter Rdg.	Amperes	Potentio Meter Rdg.	Mean amperes	Probable error of reading for low	Probable error of reading for high	
1	15.23	-	5	0.0312	5.156	0.0312	5.156			
2	.25/32	11.0	87.5	0.6058	100.1	0.6058	100.1	± 30.2	±23.4	
3	.33/40	9.65	74	0.4941	81.65	0.4916	81.25	± 2.5	0	
4	.40/45	7.70	55	0.3700	61.15	0.3693	61.04			
5	.45/49	4.7	33	0.2228	36.82	0.2230	36.86			
6	.53/56	—	—	0.0570	9.42	0.0571	9.437			
						Runner	100 amps	± 21.3	± 7.7	

No. of Obs.	Res. in strip ext. plate	Total res. in strip ext.	Res. of strip	$\frac{R}{r}$	Rise of temp. above air	Current C	C^2	Res. per cm.	Energy per cm.	Therms per sq. cm.	Emissivity per sq. cm.	Temp air
1	2940	5850	0.02523									
2	5580	8280	0.03590	1.467	129.4	100.1	10,020	6.324×10^{-5}	6.337×10^{-1}	2.953×10^{-4}	2.476×10^{-4}	
3	4820	7520	0.03362	1.333	85.8	81.3	6610	5762	3.808	1.775	2.07	
4	3955	6665	0.02976	1.180	46.4	61.0	3721	5100	1.898	8.845×10^{-3}	1.91	
5	3355	6065	0.02708	1.073	18.8	36.9	1362	4.6461	6.322×10^{-2}	2.947×10^{-2}	1.57	
6	2975	5685	0.02538	1.006	1.55	9.44	89.1	4.3149	3.875×10^{-3}	1.806×10^{-3}	1.17	

No. of Obs.	Res. in strip ext.	Total res. in strip ext.	Res. of strip	$\frac{R}{r}$	Rise of temp. above air	Current C	C^2	Res. per cm.	Energy per cm.	Therms per sq. cm.	Emissivity
1	2890	5600	0.02500								
2	5090	7800	0.03483	1.393	101.3	100.1	10,020	5.943×10^{-5}	5.955×10^{-1}	2.775×10^{-4}	2.74×10^{-4}
3	4450	7160	0.03197	1.279	71.9	81.3	6610	5.455	3.605	1.680	2.34
4	3765	6475	0.02891	1.156	40.2	61.0	3721	4.933	1.836	8.556×10^{-3}	2.13
5	3255	5965	0.02663	1.065	16.75	36.9	1362	4.5144	6.190×10^{-2}	2.885×10^{-2}	1.72
6	2920	5630	0.02514	1.0055	1.42	9.42	89.1	4.290	3.823×10^{-3}	1.782×10^{-3}	1.26

No. of strip	Condition	Rise Temp. @ 100 amperes	Emissivity	Condition	Rise of Temp. @ 100 amperes	Emissivity		Radiation on assumption of a convection loss of flat
1	Upright	102°	2.75×10^{-4}	Flat	129.4	2.48×10^{-4}		2.21×10^{-4}
5	Upright	101.3°	2.74×10^{-4}	Flat	119.8	2.45		2.16×10^{-4}

Taking the emission and temp. of the brightened wire calculated on page 6 and on the hypothesis that at any given temp. the radiation varies with the temperature, while the convection is not a function of a freely exposed surface we have

bright strip 93.7°C $\quad 5.11\,r + c = 0.1212$ therms per cm per sec

bright wire 94.7°C $\quad 0.463\,r + c = 0.03343$ - - - - -

whence $r_{94.7} = 0.01889$ and $c = 0.02447$

- $r_{93} = 0.00021 6$

where r is the radiation loss per sqc cm; per °C per sec $= 2.16 \times 10^{-4}$ therms @ 94°C

" c - - convection - per cm; length of conductor per sec $= 2.47 \times 10^{-2}$ @ 94° C.

Tests of a certain Insulating Material.

August 1st Thursday. Received from Mr Ensell a pair of moulded lamp sockets of a red insulator resembling rubber in appearance and named Boneilate. Immersed one of these in dilute H_2SO_4 for an hour and no bad effects were observable on the material but the solution was slightly colored. Then left this socket on the cylinder of the mil. engine on a sheet of paper, exposed to a temperature of about 115 °C for 6 hours. At the end of that time the material had somewhat warped cracked and darkened in color. Socket no 2 weighed in air 13.862, water 2.685 @26°C

from which the sp. g. is 1.36.

After soaking for 20 hours in water and then superficially dried = 14.10 or an increase of only 0.24 gms or 1.6 %. The dried specimen was tested for inflammability by breaking off a piece and holding the same in a Bunsen flame. The piece caught fire after a considerably amount of heating, and burned apart after removal from the flame for some time, slowly extinguishing. It is not fire proof therefore but does not nurture a flame. The soaked piece was then tested mechanically. It cut well takes a thread well, and turns well in a lathe, blunting the tool edge. It is however rather brittle and not so tough as hard rubber. In other respects it much resembles vulcanite fibre. Vulcanized fibre is less inflammable than this material, but hard rubber is much more so.

A specimen of hard rubber weighed in air 16.9820
water @26° 2.6269

A specimen of vulcanized fiber weight sp. gr. 1.183
in air 14.6461
water @26° 0.9670
sp. 1.256

Carrying Capacity of Conductors.

August 2nd Friday

With the view of determining more closely the coefficients of convection and radiation took a series on three bare bright copper wires (two of which had been used before in the out of door test) and suspended across the room on the place of the strips whose heat is given on page 7. The height of the wires was about 250 cms and their distance apart about 50. The two larger wires tested in circuit with the long range ammeter and the smaller separately in circuit with the Ohmch.

Res. of galv. coils 27200 each giz multiple in first test, series in second

No. of wire	Length	Diam.	Surface per cm.	Area	C.M.	Condition of surface	Res. per cm. @ 0°C	Resistivity @ 0°C	Conductivity %	Resistivity	Temp air
1	58.4	{0.1345 / 0.3416}	1.073	9.0916	18,200	bright	1.95×10^{-5}	1.765×10^{-5}	100%	1617	27°C
2	58.15	{0.1119 / 0.279}	0.8765	0.0611	12,100	"	2.924×10^{-5}	2.702×10^{-5}	98.1	1651	
3	58.23	{0.0356 / 0.0904}	0.2840	0.00648	1270	"	2.921×10^{-4}	2.644×10^{-4}	95.5	1697	

t° ↑ 15.2°	Coefficient of radiation	Total rad. per cm²	Energy per cm²	Convection per cm²
4.5	0.00214	0.00258	0.01504	0.00746
11.1	0.006	0.006644	0.02710	0.02066
24.2	0.0124	0.0133	0.05636	0.04306
42.8	0.0250	0.0268	0.09577	0.07699
66.5	0.0465	0.0524	0.1757	0.1233
82.2	0.0615	0.0660	0.2293	0.1623
100.2	0.0800	0.0858	0.2768	0.1910
7.3	0.004	0.00351	0.0155	0.0120
20.6	0.012	0.0105	0.0429	0.0324
44.1	0.0285	0.0250	0.09142	0.0649
68.9	0.0575	0.0504	0.1688	0.1184
125.0	0.111	0.0973	0.3171	0.2200
4.4	0.0024	0.0007	0.00516	0.00446
17.5	0.0105	0.00298	0.03110	0.0281
46.4	0.030	0.00852	0.07548	0.06696
110.8	0.093	0.0264	0.1637	0.1373

Carrying Capacity of Conductors

(13)

Mark No.	Time	E.M.F. Am	Amperes	Res. in Ω (0.0139)	Amperes	Mean Potential Drop	Mean amperes
1	14.30	—	—	0.0324	5.355	0.0325	5.371
2	38	2.1	23	0.1360	22.48	0.1363	22.53
3	45	4.75	34	0.2200	36.36	0.2206	36.46
4	55	6.9	48	0.3124	51.63	0.3108	51.37
5	15.5	8.7	63	0.3925	64.87	0.3987	65.90
6	15	10.4	80	0.5140	84.95	0.5118	84.59
7	16.5	11.2	90	0.5820	93.58	0.5698	94.18
8	18	11.9	99	0.6162	101.9	0.6117	101.1
9		Obnl.					
10	10.50	0.225	2.18	0.0500	2.004	0.0500	2.004
11	45	1.030	5.28	0.1304	5.226	0.1308	5.242
12	11.00	2.190	9.29	0.2370	9.498	0.2371	9.503
13	15	2.790	14.31	0.3690	14.790	0.3691	14.79
14	45	3.760	19.28	0.4978	19.950	0.4983	19.97

#1 No. Mes.	Res. in Ω of wire (0.0139)	Total res. in Ω of wire (0.0139)	Res. of wire	R/r	Rise of temp. in wire	Current C	C²	Res. per cm.	Watts per cm.	Watts per sq. cm. surface	Therms per sq. cm.	Conducivity
1	170	2890	0.0139					1.95×10^{-5}				
2	120	2840	0.01159	1.0175	4.51	22.53	506.3	1.984	1004×10^{-5}	2.22°	2.228×10^{-5}	5.056×10^{-5}
3	50	2770	0.01188	1.043	11.08	36.5	1332	2.035	2.710		6.014	5.428×10^{-5}
4	80	2800	0.01246	1.094	24.22	51.4	2642	2.133	5.636		1.251×10^{-4}	5.164×10^{-5}
5	265	2985	0.01328	1.166	42.77	65.9	4343	2.274	9.877		2.192	5.125×10^{-5}
6	500	3220	0.01433	1.258	66.48	84.6	7157	2.4574	1.757×10^{-1}		3.899	5.614×10^{-5}
7	655	3375	0.01502	1.319	82.20	94.2	8874	2.5722	2.283		5.068	6.165×10^{-5}
8	835	3555	0.01582	1.389	100.2	101.1	10220	2.709	2.768		6.143	6.132×10^{-5}

#2 No. Mes.	Res. in Ω (0.0139) cat with wire	Total res. in Ω wire cat.	Res. of wire	R/r	Rise of temp. in	Current C	C²	Res. per cm.	Watts per cm.	Watts per sq. cm. surface	Therms per sq. cm.	Conducivity
1	1180	3900	0.01735					2.924×10^{-5}				
2	1290	4010	0.01784	1.0282	7.27	28.54	506.3	3.068	1.553×10^{-1}		4.218×10^{-5}	5.903×10^{-5}
3	1490	4210	0.01873	1.080	20.62	36.5	1332.	3.221	4.290		1.165×10^{-4}	5.65×10^{-5}
4	1845	4565	0.02031	1.171	44.06	51.4	2642	3.565	9.416		2.558	5.804×10^{-5}
5	2360	5080	0.02260	1.303	78.08	65.9	4343	3.887	1.688×10^{-1}		4.584	5.871×10^{-5}
6	3070	5790	0.02576	1.485	125.0	84.6	7157	4.430	3.171		8.612	6.891×10^{-5}
7	3640	6360	0.02830	1.631	162.6	94.2	8874	4.867	4.319		1.173×10^{-1}	7.214×10^{-5}
8	4160	6880	0.03061	1.765	197.2	101.1	10220	5.264	5.379		1.461	7.406×10^{-5}

#3 No. Mes.	Res. in Ω (0.0139) cat with wire	Total res. in Ω wire cat.	Res. of wire	R/r	Rise of temp. above air	Current C	C²	Res. per cm.	Watts per cm.	Watts per sq. cm. surface	Therms per sq. cm. surface	Conducivity
1	6550	9270	0.07010					2.921×10^{-4}				
2	6710	9430	0.1750	1.017	4.39	5.24	27.46	2.970	8.156×10^{-3}		6.936×10^{-3}	1.561×10^{-3}
3	7175	9895	0.1816	1.068	17.52	9.50	90.25	3.118	3.110×10^{-2}		2.607×10^{-2}	1.494×10^{-3}
4	8220	10940	0.2007	1.180	46.39	14.79	219.0	3.446	7.568		6.327	1.364×10^{-3}
5	10535	13255	0.2432	1.430	110.8	19.77	391.0	4.176	1.637×10^{-1}		1.372×10^{-1}	1.238×10^{-3}

10°

5·11 r + c = 0·043
0·2841 r + c = 0·020
4·826 r = 0·023
r = 0·004765
c = 0·01865

20°

5·11 r + c = 0·037
0·2841 r + c = 0·036
4·826 r = 0·051
r = 0·01057
c = 0·0338

30°

5·11 r + c = 0·135
0·2841 r + c = 0·052
4·826 r = 0·083
r = 0·01720
c = 0·04471

40°

5·11 r + c = 0·1641
0·2841 r + c = 0·065
4·826 r = 0·119
r = 0·02466
c = 0·0580

50°

5·11 r + c = 0·235
0·2841 r + c = 0·080
4·826 r = 0·155
r = 0·03212
c = 0·0709

60°

5·11 r + c = 0·293
0·2841 r + c = 0·094
4·826 r = 0·198
r = 0·04103
c = 0·0824

70°

5·11 r + c = 0·350
0·2841 r + c = 0·109
4·826 r = 0·241
r = 0·04995
c = 0·0958

80°

5·11 r + c = 0·407
0·2841 r + c = 0·121
4·826 r = 0·286
r = 0·05927
c = 0·1042

90°

5·11 r + c = 0·4612
0·2841 r + c = 0·136
4·826 r = 0·328
r = 0·06796
c = 0·1167

100°

5·11 r + c = 0·525
0·2841 r + c = 0·149
4·826 r = 0·376
r = 0·0779
c = 0·1289

10°

1·0737 r + c = 0·026
0·2841 r + c = 0·020
0·789 r = 0·026
r = 0·0336
c = 0·0336

20°

1·0737 r + c = 0·051
0·2841 r + c = 0·036
0·789 r = 0·015
r = 0·0190
c = 0·0306

30°

1·0737 r + c = 0·079
0·2841 r + c = 0·052
0·789 r = 0·027
r = 0·0342
c = 0·0423

40°

1·0737 r + c = 0·106
0·2841 r + c = 0·065
0·789 r = 0·041
r = 0·05196
c = 0·050

50°

5·11 r + c = 0·184
1·0737 r + c = 0·106
4·037 r = 0·078
r = 0·07932
c = 0·0853

Carrying Capacity of Conductors.

From the observed dissipation of heat by the bright, bare suspended copper wire and strip we obtain the following analysis of the convective and radiative emissivity at different temperature elevations.

Elev. temp. °C	Wire selected	Total convection watts	Total convection therms.	Radiation per sq. cm. Watts	Radiation per sq. cm. therms.	Radiation per sq. cm. Watts	Radiation per sq. cm. therms.	Adjusted Radiations 40° C.	Adjusted Radiations 40° C.	Adjusted Radiation per sq. Watts		To follow 30° table not Watts
10°		0·01865	0·004444	0·004765	0·001134	0·000477	0·000113	0·000113	0·000047	+ 0·000066	0·005337
20°		0·0338	0·00786	0·01057	0·002516	0·000529	0·000126	0·000126	0·000529	+ 0·000063	0·01120
30°	Bright strip	0·04471	0·01121	0·01720	0·004095	0·000573	0·000136	0·000137	0·000575	+ 0·00018	0·01738
40°	1 doubled wire diam.	0·0580	0·01381	0·02466	0·005871	0·000617	0·000147	0·000147	0·000617	−0·000040	0·02426
50°		0·0709	0·01688	0·03212	0·007648	0·000642	0·000153	0·000155	0·000650	−0·000082	0·03160
60°	0·0906	0·0824	0·01962	0·04103	0·009768	0·000684	0·000163	0·000163	0·000684	−0·00154	0·03949
70°		0·0958	0·02287	0·04995	0·011890	0·000714	0·000170	0·000170	0·000714	−0·00193	0·04862
80°		0·1042	0·02481	0·05927	0·01411	0·000741	0·000176	0·000176	0·000741	−0·00204	0·05723
90°		0·1167	0·02778	0·06796	0·01618	0·000755	0·000180	0·000181	0·000760	−0·00078	0·06718
100°		0·1289	0·03022	0·07790	0·01855	0·000779	0·000185	0·000185	0·000779		0·07790

An examination of the results obtained by Mm. Dulong + Petit express the law of emissivity by the equation:

$$e = m\,t^{(1.233)} + n\{(1.0077)^t - 1\}$$

where t is the temp: elevation in °C and m + n are constants

	ratio 1.20°	ratio 1.20°
$1.0077^{10} - 1 = 0.0793$		
$1.0077^{20} - 1 = 0.1658$		1·0
$1.0077^{30} - 1 = 0.2592$	1·0	1·551
$1.0077^{40} - 1 = 0.3591$	1·396	2·166
$1.0077^{50} - 1 = 0.4678$	1·819	2·822
$1.0077^{60} - 1 = 0.5845$	2·273	3·526
$1.0077^{70} - 1 = 0.7108$	2·764	4·287
$1.0077^{80} - 1 = 0.8471$	3·294	5·109
$1.0077^{90} - 1 = 0.9944$	3·866	5·991
$1.0077^{100} - 1 = 1.1534$	4·485	6·957

Elev. temp. °C	Calculated rate per sq. cm. Watts as above		Calc: rate from 30° in last table by Dulong + Petit law	Calc: rate from 30° in this by power law	Difference		
10°	0·004765	1	0·005301	0·005365	+ 0·000068		
20°	0·01057	2·2	0·01109	0·01188	+ 0·000081		
30°	0·01720		0·01720 ←	0·01766	+ 0·000046		
40°	0·02466	1·5	0·02401	0·02466 ←			
50°	0·03212	1·4	0·03128	0·03212	0		
60°	0·04103	1·28	0·03908	0·04013	− 0·000090		
70°	0·04995	1·22	0·04753	0·04881	− 0·000114		
80°	0·05927	1·22	0·05665	0·05816	− 0·000111		
90°	0·06796	1·18	0·06648	0·06826	+ 0·000030		
100°	0·07790	1·16	0·07714	0·07919	+ 0·00129		

This very remarkable agreement proves the application of Dulong + Petit's law.

do that @ 30° $n\{1.0077^{30} - 1\} = 0.02466$ Watts $\therefore n = 0.02466/0.2592 = 0.06866$ Watts

@ 100° $m\{1.0077^{100} - 1\} = 0.07919$. $\therefore n = 0.07919/1.1534 = 0.06866$

Also $m \times 1.0077^{33} = 0.06866$ Watts.

$\therefore m = 0.06866/1.2207 = 0.05625$

+ the complete expression for the radiation of a bright wire t° above the surrounding air at θ°C is

$$r = 0.05625\,(1.0077)^{\theta}\{1.0077^{t} - 1\}$$ Watts per sq. cm

Carrying Capacity of Phonograph Double cord.

In the present form of strand phonograph conductor there are 79 wires each 0.0088" diam: = 77.5 c.m. each × 79 = 6125 c.m. in all. That is practically equivalent to a number 14 B.W.G.

The accepted limit of the length of this strand that can be used with the phonograph is 12 feet doubled = 24 feet.

= 24 × 0.0015 = 0.0360 ω

20 feet distance	=	40 feet of wire	=	0.0009 ω per ft	=	0.109"	# 12 B.W.G.	# 9 B.W.G.
30 - -	=	60 - - - -	=	0.00006 ω - - -	=	0.1324"	# 10 B.W.G.	# 8
40 - -	=	80 - - - -	=	0.00045 ω - - -	=	0.1148"	# 9 B.W.G.	# 7
50 - -	=	100 - - - -	=	0.00036 ω - - -	=	0.165"	# 8 B.W.G.	# 6
75 - -	=	150 - - - -	=	0.00024 ω - - -	=	0.203"	# 6 B.W.G.	# 4
100 - -	=	200 - - - -	=	0.00018 ω - - -	=	0.258"	# 4 B.W.G.	# 3
150 - -	=	300 - - - -	=	0.00012 ω - - -	=	0.286"	# 2 B.W.G.	# 1
200 - -	=	400 - - - -	=	0.00009 ω - - -	=	0.320"	# 0 B.W.G.	# 0

August 6th Tuesday.

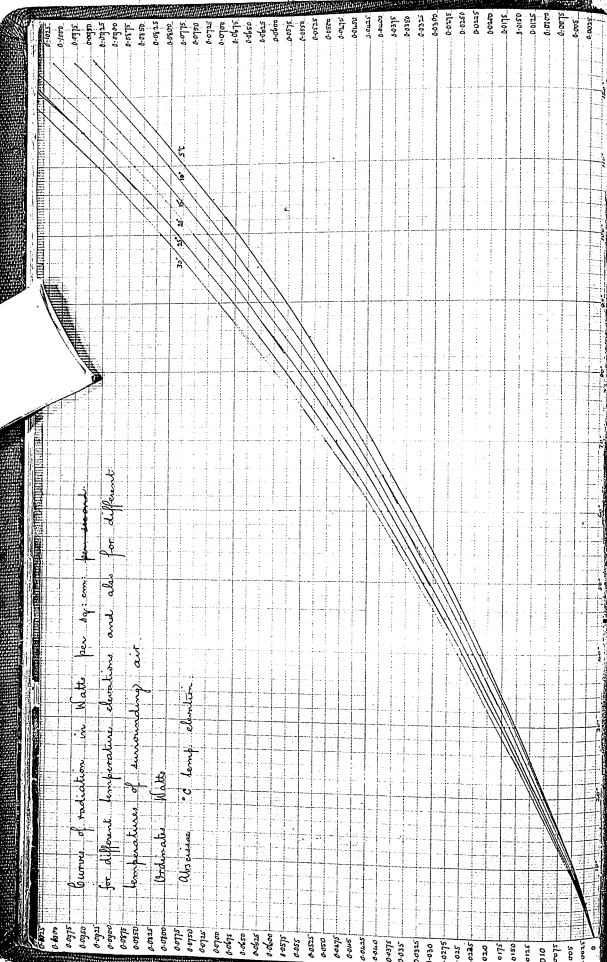
Found by experiment at the Phonograph Works with Frank Osborne that a 4 cell potash battery that has been ~~a~~ working for forty hours, operated a phonograph (fair sample) satisfactorily through 25 feet of bare soft copper wire 0.058" (0.14173 cm) diameter. The res: per cm: of this wire (vide p. 6) is 1.056×10^{-6} ω per cm. = 32.6×10^{-6} ω per foot = 815×10^{-4} or 0.0815 ω for 25 feet. Let us say 22.0 feet of this wire to give a good margin. On this basis 0.0650 ω

Distance	Length wire	Res: per foot	Total res	Diam: wire	Nearest B.W.G. gauge	Nearest B.&S. gauge	
10 20 feet	40 20 feet	0.00162	0.0650 ω	0.058"	# 15	# 12	
30 -	60	0.00108	~~0.0650~~	0.096"	# 13	# 10	
40 -	80	0.00081		0.111	# 12	# 9	
50 -	100	0.00065		0.127	# 10	# 8	
75 -	150	0.000433		0.153	# 8	# 6	
100 -	200	0.000325		0.180	# 7	# 5	
150 -	300	0.000217		0.220	# 5	# 3	
200 -	400	0.000163		0.250	# 3	# 2	

Test of an overmilling horse shoe flat magnet on 5th August for Mr Dixon. 13.4 ω on each link variable as though some bad contact in each, and 6.7 ω in multiple arc. # 14 B.W.G. wire.

Meteorological Record.

Date	Time	Barometer Inches	Barometer Cms	Rdg. Temp. of Barom. in Mm	Rdg. Temp. of Barom. in °C	Thermom. rdgs Max	Thermom. rdgs Min	Thermom. rdgs Dry	Thermom. rdgs Wet	Rainfall last 24 hrs	Clouds	Wind	Weather remarks
August	Noon	29.862	75.87	75°	29.733	84°	60°	79°	76°	1.31"	-	NE	Raining
1.													
2.		29.931	76.05	77°	29.801	88°	58°	81°	77°	—	-	W	Fair
3		30.024	76.26	75	29.895	82°	61°	80°	75°	0.62"	-	SW	Raining & hailstorm
4		30.034	76.30	75	29.909	87°	65°	77°	72°	—	-	WSW	Fine
5		29.994	76.17	74°	29.868	86°	63°	78°	76°	0.14"	-	S	Overcast
" 6	"	30.088	76.48	72°	29.964	80°	60°	71°	67	—	-	E	Fine
7		30.024	76.26	74°	29.898	81°	61°	78°	74°	—	-	SE.	Fair
8		30.066	76.36	73°	29.963	82°	60°	81°	75°	0.40"	-	W	Fine
9		29.944	76.14	72°	29.864	84°	60°	74°	71°	—	-	W	Fair, overcast.
10		29.756	75.73	75°	29.624	78°	69°	77°	74°	0.20"	-	SW	Rain, overcast
11		29.824	75.75	77°	29.698	82°	62°	80°	76°	—	-	W	Fine
12		30.020	76.24	70°	29.906	80	62°	70	65	—	-	W	Fine.
" 13	"	30.062	76.34	72°	29.942	79°	55°	78°	74°	—	-	NW	Fair
14		29.704	75.46	74°	29.578	78°	52°	79°	75	1.80"	-	SW	Fair
15		29.726	75.54	76°	29.610	82°	55°	79°	75°	0.06"	-	SW	Overcast
16		30.042	76.31	76°	29.910	78°	56°	78°	74°	—	-	SW	Fair
17		30.120	76.50	74°	29.994	81°	62°	79°	72°	—	-	W	Fine
18		29.990	76.15	77°	29.855	83°	61°	81°	78°	—	-	NW	Fine.
19		29.996	76.18	78°	29.838	82°	60°	78°	76°	—	-	SW	Fair
" 20	"	29.834	75.88	76°	29.702	82°	54°	81°	76°	—	-	SW	Fine
21		29.990	76.15	74°	29.864	87°	59°	83°	76°	—	-	E	Fair
22		29.946	76.04	76°	29.814	86°	72°	82°	76°	—	-	NE	Overcast.
23		29.940	75.98	75°	29.781	84°	68°	79°	76°	—	-	W	Overcast.
24		30.014	76.24	75°	29.895	82°	70°	80°	76°	0.30"	-	NW	Fair, overcast.
25		30.132	76.54	75°	30.003	81°	64°	78°	70°	—	-	W	Fine
" 26		29.948	76.09	76°	29.812	80°	61°	74°	70°	—	-	W	Fair
27	"	29.848	75.92	76°	29.712	78°	54°	74°	69°	—	-	W	Fair
28		29.104	76.42	75°	29.975	79°	52°	77°	70°	—	-	NE.	Fair
29		30.118	76.50	76°	29.986	84°	50°	78°	71°	—	-	NE	Fair
30		30.030	76.45	77°	29.945	82°	56°	79°	69°	—	-	E	Fine.
31		29.982	76.15	78°	29.844	85°	64°	82°	75°	—	-	NW	Fine
Sept. 1		29.864	75.87	77°	29.729	81°	61°	80°	73°	—	-	W.NW	Fair
2		29.992	76.15	74°	29.866	80°	60°	78°	72°	—	-	N	Fair. Heavy
3		30.122	76.52	77°	29.987	79°	54°	77°	71°	—	-	W	Fair. Heavy
4		30.026	76.27	76°	29.954	83°	59°	80°	74°	—	-	NW	Fair. Heavy
5		30.032	76.28	74°	29.906	83°	56°	75	69°	—	-	S.	Fair. Nights
6		29.914	76.12	78°	29.776	80°	65°	80°	75°	—	-	S	Fair
7		30.020	76.25	74°	29.894	81°	62°	75°	73°	0.41"	-	NW	Overcast
8		29.994	76.19	76°	29.862	78°	59°	78°	72°	—	-	W	Fair
9		30.032	76.29	74°	29.906	79°	56°	75°	70°	—	-	NE	Overcast
10		29.940	75.90	70°	29.726	78°	60°	65°	64°	0.25"	-	NE	Showery
11		29.776	75.64	66°	29.674	75°	62°	63°	63°	0.20"	-	"	"
12		29.962	76.11	69°	29.854	70°	58°	68°	63°	1.42"	-	N	"
13		29.876	75.92	67°	29.771	71°	60°	68°	65°	2.09"	-	N	"
14		29.984	76.16	68°	29.876	72°	59°	69°	69°	0.38"	-	NE	Fair
15		29.992	76.19	72°	29.872	74°	63°	74°	74°	0.06"	-	W	Fair
16		29.924	76.01	74°	29.798	73°	60°	74°	72°	0.72"	-	S	Fair
17		29.850	75.81	75°	29.721	77°	68°	75°	75°	0.06"	-	SW	Raining
18		29.750	75.55	77°	29.645	79°	64°	69°	66°	4.06"	-	W	Overcast.
19		29.582	75.02	68°	29.433	74°	52°	68°	66°	—	-	W	Fair
20		29.862	75.86	66°	29.786	70°	49°	59°	55°	—	-	W	Overcast
21		29.984	76.14	68°	29.891	69°	46°	76°	55°	—	-	W	Fair
22		29.972	76.10	65°	29.871	71°	43°	66°	58°	—	-	W	Fine
23		30.000	76.20	66°	29.898	61°	42°	56°	52°	—	-	W	Fine
24		30.032	76.28	64	29.936	60°	45°	56	60	—	-	W	Overcast.
25		29.920	76.00	68°	29.827	69°	47°	65°	63°	0.38"	-	E	Raining
26		29.750	75.55	70°	29.621	69°	45°	68°	65°	0.81"	-	NE	Overcast
27		29.924	76.00	76°	29.822	72°	45°	64°	49°	0.06"	-	W	Fine
28		30.050	76.32	76°	29.918	76°	43°	77°	66°	—	-	W	Fine
29		29.998	76.19	76°	29.862	79°	46°	78°	67°	—	-	NW	Fair
30		29.836	75.83	75°	29.707	76°	52°	66°	64°	—	-	N	Overcast



Carrying Capacity of Conductors.

For convenience in calculating the radiation from conductors the following table gives the temp: elevation coefficient.

t°C	log 1·0077	t log 1·0077	$1{\cdot}0077^t$	$1{\cdot}0077^t - 1$	θ 5° $0{\cdot}05625(1{\cdot}0077^t - 1)$	θ 10°	θ 15°	θ 20°	θ 25°
					0·00281				
5	0·0033313	0·0166565	1·0391	0·0391	0·002285	0·0207231	0·0531168	0·0655762	0·0611113
10		0·0333130	1·0797	0·0797	0·004658	0·002375	0·002467	0·002564	0·002665
15		0·0499695	1·1219	0·1219	0·007125	0·004840	0·005020	0·005228	0·005431
20		0·0666260	1·1658	0·1658	0·009691	0·007402	0·007692	0·007994	0·008306
25		0·0832825	1·2114	0·2114	0·012364	0·009691	0·0007	0·01046	0·01087	0·01130
30		0·0999390	1·2587	0·2587	0·015112	0·012364	0·01034	0·01087	0·01144
35		0·1165955	1·3080	0·3080	0·018000	0·015112	0·01071	0·01632	0·01697	0·01763
40		0·1332520	1·3591	0·3591	0·02099	0·018000	0·01871	0·07943	0·02020	0·02099
45		0·1499085	1·4123	0·4123	0·024110	0·02181	0·02266	0·02356	0·02447
50		0·1665650	1·4675	0·4675	0·02733	0·025004	0·02602	0·02704	0·02810
55		0·1832215	1·5249	0·5249	0·03068	0·02839	0·02950	0·03067	0·03187
60		0·1998780	1·5844	0·5844	0·03416	0·03188	0·03312	0·03443	0·03578
65		0·2165345	1·6464	0·6464	0·03778	0·03550	0·03688	0·03833	0·03984
70		0·2331910	1·7108	0·7108	0·04155	0·03926	0·04080	0·04240	0·04406
75		0·2498475	1·7777	0·7777	0·04546	0·04317	0·04484	0·04662	0·04845
80		0·2665040	1·8471	0·8471	0·04951	0·04724	0·04904	0·05097	0·05296
85		0·2831605	1·9194	0·9194	0·05374	0·05145	0·05346	0·05556	0·05774
90		0·2998170	1·9944	0·9944	0·05812	0·05584	0·05802	0·06030	0·06266
95		0·3164735	2·0724	1·0724	0·06268	0·06040	0·06275	0·06522	0·06778
100		0·3331300	2·1534	1·1534	0·06742	0·06513	0·06768	0·07032	0·07308
105		0·3497865	2·2376	1·2376	0·07234	0·07006	0·07278	0·07565	0·07859
110		0·3664430	2·3251	1·3251	0·07745	0·07518	0·07810	0·08116	0·08434
115		0·3830995	2·4161	1·4161	0·08277	0·08048	0·08363	0·08690	0·09029
120		0·3997560	2·5105	1·5105	0·08824	0·08600	0·08935	0·09286	0·09650
125		0·4164125	2·6086	1·6086	0·09402	0·09175	0·09532	0·09906	0·10032
						0·0977	0·10150	0·10550	0·10976

If ρ be the sp: resistivity of a conductor at the limiting temp:
d - - its diameter
t - - elevation of temp. in °C
θ - the temp: of surrounding bodies
m - - coefficient of radiation
c - - strength of current in abs: units

Then the heat generated in watts per cm. is

$\frac{4c^2\rho}{\pi d^2} \times 10^{-7}$ and the heat dissipated is per cm in Watts

$kt\theta + m a^\theta (a^t - 1)\pi d\theta$ where

k is the convection coefficient 0·00175
a - - radiation - 1·0077
m - - surface " "

$$\therefore \quad 4c^2\rho \times 10^{-7} = kt d^2 + \pi m a^\theta (a^t - 1) d^2$$

$$c = \frac{\pi}{2}\sqrt{\frac{10^7\{kt d^2 + \pi m a^\theta (a^t - 1) d^2\}}{\rho}}$$

$$= \frac{\pi 10^4}{6{\cdot}2246}\sqrt{\frac{d^2\{kt + \pi m a^\theta (a^t - 1) d\}}{\rho(1 + at)}}$$

$$= 1581\, d \sqrt{\left\{\frac{kt + m\pi a^\theta (a^t - 1) d}{\rho(1 + bt)}\right\}} \quad \text{where } b = 0{\cdot}00388$$

$$= 1581\, d \sqrt{\left\{\frac{0{\cdot}00175 t + d m \pi \times \lambda}{\rho(1 + bt)}\right\}} \quad \text{where } \lambda \text{ is from above table } a^\theta(a^t - 1)$$

$$\text{in amperes} = 15810\, d \sqrt{\left(\frac{0{\cdot}00175 t + d m \pi \lambda}{\rho(1 + bt)}\right)} = 28{\cdot}9\, d \sqrt{\left\{\frac{0{\cdot}00175 R_0 + t}{1 + 0{\cdot}00388 t}\right\}}$$

where $R_0 = \lambda$

d	dt	$7.4\,dt$	$570\,\pi d_R t^{1.61}$	v	c	$1140\,\pi d_R t^{1.61}$	$\sqrt{}$	c
$d=0.1$								
5	0.5	0.3.7 3.7	5.80 9.46	2.62	6.98 8.37	6.29	2.51	15.93 3.96
10	1.0	0.7.4 7.4	18.68	2.42	9.36 10.1	12.67	3.55	9.471 12.0
20	2.0	14.8 14.8	53.95	2.84	12.01 14.3	25.42	4.87	13.41 16.4
40	4.0	29.6 29.6	173.18	3.87	17.9 21.4	74.77	6.91	18.60 22.6
$d=0.3$								
5	0.15	12.1	18.48	4.3	35.6	19.86	4.46	36.9
10	0.30	22.2	35.01	5.92	48.6	37.15	6.1	50.1
20	0.60	44.4	70.24	8.38	67.56	76.08	8.72	70.3
40	1.20	88.8	141.14	11.9	92.96	154.0	12.4	96.87
$d=0.5$								
5	2.5	18.5	25.79	5.08	70.2	28.08	5.30	73.2
10	5.0	37.0	51.68	7.19	98.4	56.36	7.51	102.7
20	10.0	74	103.74	10.2	137.1	113.47	10.65	143.1
40	20.0	148	209.1	14.5	189	230.2	15.2	198
$d=0.7$								
5	3.5	25.9	34.12	5.84	113	40.33	6.35	123
10	7.0	51.8	68.16	8.26	158	74.5	8.63	165
20	14.0	103.6	137.23	11.7	220	160.9	12.55	238
40	28.0	207.2	276.77	16.6	303	326.3	17.5	319
$d=1.0$								
5	5	37	46.59	6.83	189	51.19	7.21	199
10	10	74	93.36	9.66	264	102.7	10.1	276
20	20	148	187.5	13.7	368	198.9	14.1	379
40	40	296	378.2	19.46	507	420.4	20.5	534
$d=1.5$								
5	6.25	46.25	57.0	7.55	261	62.73	7.92	273
10	12.5	92.5	114.2	10.7	366	125.9	11.2	383
20	25	185	229.3	15.15	509	254.2	15.95	536
40	50	370	462.8	21.5	701	515.5	22.7	740

T	$0.003287T$	$1+0.003287T$	$\sqrt{1+0.003287T}$	$\frac{28.9}{\sqrt{1+0.003287T}}$
20°	0.0776	1.0776	1.0373	27.87
30°	0.1164	1.1164	1.0566	27.36
40°	0.1552	1.1552	1.0748	26.88
50°	0.1940	1.1940	1.0927	26.45
60°	0.2328	1.2328	1.110	26.02
70°	0.2716	1.2716	1.1276	25.64
80°	0.3104	1.3104	1.1447	25.25
90°	0.3492	1.3492	1.1615	24.88
100°	0.3880	1.3880	1.1781	24.53
110°	0.4268	1.4268	1.1945	24.19
120°	0.4656	1.4656	1.2106	23.87

t	R_t	$d=0.1$ πd_R	$570\,\pi d_R$	$1140\,\pi d_R$	$\sqrt{570\,\pi d_R t^{1.61}}$	$\frac{28.9}{\sqrt{1+0.003287t}}$	$\frac{28.9\,d}{\sqrt{1+0.003287t}}$	$\frac{28.9\,d\sqrt{570\,\pi d_R t}}{\sqrt{1+0.003287t}}$	$\sqrt{1140\,\pi d_R t}$	$\frac{28.9\,d\sqrt{1140\,\pi d_R t}}{\sqrt{1+0.003287t}}$
5	0.002542	0.000806	0.4596	0.9190	2.34	27.61	0.646	2.43	6.71	
10	0.005228	0.001602	0.9360	1.873	3.31	27.36	0.966	3.44	9.41	
20	0.01037	0.003214	1.946	2.219	4.68	26.88	1.257	4.72	12.69	
40	0.02356	0.007402	4.220	4.812	6.65	26.04	1.732	6.69	17.42	
80	0.05556	0.01749	9.970	11.37	9.485	24.53	2.326	9.56	23.46	
t	$d=0.3$ πd_R	$570\,\pi d_R$	$1140\,\pi d_R$	$\sqrt{570\,\pi d_R t}$	$\frac{28.9}{\sqrt{1+0.003287t}}$	$\frac{28.9\,d}{\sqrt{1+0.003287t}}$		$\sqrt{570\,\pi d_R t}$		
5	0.002417	0.378	2.756	2.79	27.61	8.283	23.1	2.58	20.95	
10	0.004929	2.810	5.620	3.95	27.36	8.208	32.4	3.58	29.29	
20	0.01025	5.842	11.684	5.63	26.88	8.064	45.4	5.07	40.96	
40	0.02210	12.60	25.2	8.07	26.04	7.812	63.1	7.25	56.65	
80	0.05238	29.86	59.72	11.90	24.53	7.359	86.8	10.45	76.9	
t	πd_R	$d=0.5$ $570\,\pi d_R$	$\sqrt{570\,\pi d_R t}$	$\frac{28.9\,d\sqrt{570\,\pi d_R t}}{\sqrt{1+0.003287t}}$	$\sqrt{1140\,\pi d_R t}$	$\frac{28.9\,d\sqrt{1140\,\pi d_R t}}{\sqrt{1+0.003287t}}$	$\frac{28.9\,d}{\sqrt{1+0.003287t}}$	$\frac{28.9\,d}{\sqrt{1+0.003287t}}$		
5	0.002022	2.292	2.70	37.3	4.584	3.09	42.7	27.61	13.81	
10	0.004213	4.682	3.83	52.4	9.364	4.40	60.8	27.36	13.68	
20	0.07787	9.735	5.45	73.26	19.470	6.28	86.8	26.88	13.44	
40	0.03701	21.10	7.82	101.8	42.20	9.07	125.3	26.04	13.02	
80	0.08728	49.76	11.4	139.9	99.52	13.4	185.1	24.53	12.27	
5 (0.07)	0.00566	3.215	2.87	55.47	6.43	3.38	65.34	27.61	19.33	
10	0.01180	6.356	4.04	77.42	12.71	4.77	91.4	27.36	19.16	
20	0.02391	13.63	5.80	109.2	27.26	6.87	129.3	26.88	18.82	
40	0.05182	29.55	8.34	152.1	59.10	9.95	181.4	26.04	18.23	
80 (0.1)	0.1223	69.70	12.25	210.4	139.40	14.8	254.2	24.53	17.17	
5 (0.12)	0.00656	4.593	3.10	85.6	9.18	3.77	104.1	27.61	27.61	
10	0.01643	9.360	4.40	120.4	18.73	5.36	147	27.36	27.32	
20	0.03415	19.46	6.28	169	38.92	7.68	207	26.88	26.88	
40	0.07402	42.20	9.07	236	84.4	11.15	290	26.04	26.04	
80	0.17477	99.58	13.4	329	199.2	16.7	410	24.53	24.53	
5 (0.15)	0.0707	5.74	3.28	113.1	11.48	4.06	140	27.61	34.5	
10	0.02053	11.70	4.66	157.4	23.4	5.78	198	27.36	34.2	
20	0.04269	24.34	6.66	224	48.68	8.29	279	26.88	33.6	
40	0.09254	52.75	9.63	314	105.5	12.1	395	26.04	32.6	
80	0.21820	124.44	14.3	439	248.8	18.1	555	24.53	30.67	

Formulae for wires in still air

Heat generated watts per cm = Heat conducted watts per cm + Heat radiated watts per cm

$$\frac{4c^2\rho\,(1+0.00388T)}{\pi d^3} = 0.00175\,t + m\pi d R_t$$

$$\therefore\ c = 0.886\,d\sqrt{\frac{m\pi d R_t + 0.00175t}{\rho(1+0.00388T)}}$$

for copper 98% cond. $\rho = 1.65\times10^{-6}$ ω.
" bright copper $m = 1$
" blackened " $= 2$

$$\therefore\ c = 28.9\,d\sqrt{\frac{570\,a R_t + t}{1+0.00388T}} \quad \text{bright}$$

$$= 28.9\,d\sqrt{\frac{1140\,a R_t + t}{1+0.00388T}} \quad \text{blackened}$$

where d = diam. wire in cms:
t = temp. elevation
θ = " of surrounding air
T = t + θ the temp. of wire at rest
a = circumference of wire cms
c = current amperes.

If D be measured in inches these become

$$c = 73.4\,D\sqrt{\frac{1450\,a R_t + t}{1+0.00388T}}$$

$$= 73.4\,D\sqrt{\frac{2900\,a R_t + t}{1+0.00388T}}$$

On the winding of a small motor to have ¼ H.P. or 2 man power, to be as light as possible.

The armature to be 6" long 5" diam: and of the drum type.
The e.m.f. to be 50 volts. The thickness of the armature to be ½". The speed to be about 1800 revs: per min.
If an average field of 600 lines be assumed, the peripheral speed is $15.7 \times 2.54 \times 30 = 1200$ cms per sec: so that the length of effective wire will be $50\times10^8 \div 600\times1200 = 5.0\times10^8 \div 7.2\times10^5 = 6.94\times10^3 = 6940$ cms: on each half of the cylinder = 13880 cms: in all. For four amperes at 500 c.m. the drum must be 2000 c.m. thus allowing 2×4 amperes to pass on full load. $\sqrt{2000} = 44.7 = 0.0447$" diam. The nearest B.W.G. is 0.0402" #19 wire which has a res: per foot of 0.00579 ω.

The effective res: of the armature would be $\frac{6940}{2} \times \frac{0.00579}{30} = \frac{6.94\times5.79}{60}\times10^{-3} = 0.68$ ω. The diameter of the wire covered would be 0.042 + 0.020 = 0.062 and the no: of turns possible on the cylinder $\frac{15.7\times1000}{62} = 253$. The effective length has to be 13880 ÷ 30 = 462 feet = 2 layers of wire. The actual resistance would probably be double this effective res: owing to the crossing of the wire = 1.36 ω and the total length of wire would be about 1000 feet = 5.34 lbs.

The magnets will be 6" wide, inclined 14" long and ½" thick. The surface for wire will be 8"×6" = 48 sq. ins. and the ceiling space ½" on each face = 48 × ½ = 24 cubic in:. To allow one 2 ampere to pass, the res: must be 25 ω and allowing 500 c.m. = 1000 cm. = 0.0332" diam = #29 wire the res: of this would be too high $24 \div (d^2 + 0.018)^2$ = length in inches = #23 B.W.G. = 0.0565 ω per ω = 1500 feet = 1400 turns 0.014" covered diam = 56" lineal = 7 layers = ¼" high. = 25 × 0.114 = 3.8 lbs of wire = 2800 ampere turns

Carrying Capacity of wires

Tabulated statement of the current required to raise the temperature of bare bright and blackened wire a given amount in still air

Diameter		5°C		10°C		20°C		40°C		80°C		
cms	In	Bright	Blackened	Bright	Blackened	Bright	Blackened	Bright	Blackened	Bright	Blackened	
0.1	0.0394	6.5	6.7	9.1	9.4	12.6	12.8	17.3	17.4	23.3	23.5	Rather in excess convection being too large
0.3	0.118	21.0	23.1	29.4	32.4	41.0	45.4	56.7	63.1	76.9	86.8	
.5	0.199	37.3	42.7	52.4	60.8	73.3	86.8	101.8	125.3	139.9	185.1	
.7	0.2756	55.5	65.3	77.4	91.4	109.2	129	152.	181	210	254	
1.0	0.3937	85.6	104	120	147	169	207	236	290	329	410	
1.25	0.4921	113.	140	159	198	224	279	314	395	439	555	
1.5	0.5904	143	179	201	253	283	357	398	504	558	714	
1.75	0.6889	174	222	246	313	346	441	488	625	684	888	
2.0	0.7873	208	267	293	377	413	532	583	750	819	1070	
2.5	0.9840	280	365	395	516	557	729	788	1035	1110	1470	

	5° 0.002564		10° 0.005226		20° 0.01037		40° 0.02356		80° 0.05556	
t	td	7.4 td	570 td/t	√	c	1100 td/(1+td)	√	c		
0.25										
5	7.5	55.5	67.29	8.21	340	74.29	8.62	357		
10	15	111	135.1	11.6	476	149.1	12.2	501		
20	30	222	271.2	16.5	665	307.4	17.3	698		
40	60	444	547.3	23.4	914	610.6	24.7	965		
1.75										
5	8.75	64.75	77.78	8.82	426	85.81	9.26	447		
10	17.5	129.5	155.9	12.5	599	172.3	13.1	627		
20	35	259	313.1	17.7	832	347.1	18.6	874		
40	70	518	631.8	25.1	1140	705.6	26.6	1210		
2.0										
5	10	74.0	88.2	9.39	518	97.4	9.87	545		
10	20	148	176.7	13.3	728	195.4	14.0	766		
20	40	296	354.9	18.84	1010	393.9	19.85	1067		
40	80	592	716.4	26.8	1400	800.7	28.3	1470		
2.5										
5	12.5	92.5	109	10.45	721	120.4	11.0	759		
10	25	185	218.4	14.8	1010	244.9	15.55	1060		
20	50	370	438.7	20.95	1410	487.3	22.1	1485		
40	100	740	888.5	29.75	1940	1091	33.0	2150		

Calculations of Carrying Capacity of wires.

(20)

t	td/t	570 td/t	√570 td/t	c	1100 td/(1+td)	√1100 td/(1+t)	c	28.9 / √(1+0.00367t)	32.9 / √(1+0.00367t)
0.25									
5°	0.01308	6.89	3.45	143	13.78	4.33	179	27.61	41.4
10°	0.02464	14.05	4.90	201	28.1	6.17	253	27.36	41.04
20°	0.05122	29.2	7.02	283	58.4	8.85	357	26.88	40.32
40°	0.1110	63.3	10.2	398	126.6	12.9	504	26.04	39.06
80°	0.2619	149.	15.15	558	298	19.4	714	24.53	36.80
1.75									
5°	0.01409	8.03	3.61	174	16.06	4.59	222	27.61	48.3
10°	0.02875	16.39	5.14	246	32.78	6.54	313	27.36	47.9
20°	0.05977	34.07	7.35	346	68.14	9.29	441	26.88	47.0
40°	0.1295	73.8	10.7	488	147.6	13.7	625	26.04	45.6
80°	0.3054	174.0	15.95	684	348.0	20.7	888	24.53	42.9
2.0									
5°	0.01611	9.18	3.76	208	18.36	4.83	267	27.61	55.22
10°	0.03284	18.72	5.26	293	37.44	6.89	377	27.36	54.72
20°	0.06833	38.94	7.68	413	77.88	9.89	532	26.88	53.76
40°	0.14480	84.36	11.2	583	168.72	14.4	750	26.04	52.08
80°	0.3491	199.0	14.7	819	398.	21.9	1074	24.53	49.06
2.5									
5°	0.02013	11.47	4.06	280	22.94	5.29	365	27.61	69.03
10°	0.04106	23.41	5.78	395	46.82	7.54	516	27.36	68.4
20°	0.08537	48.66	8.29	557	97.32	10.85	729	26.88	67.2
40°	0.18500	105.5	12.1	788	211.	15.9	1035	26.04	65.1
80°	0.4363	248.7	18.1	1110	497.4	24.0	1470	24.53	61.3

Table of minimum current strength in ampères required to elevate the temperature of bare copper wires in air overhead in calm weather.

Diam		5°C		10°C		20°C		40°C		
	In	Bright	Blackened	Bright	Blackened	Bright	Blackened	Bright	Blackened	
0.1	0.03937	8.4	8.96	14.4	12.0	16.3	16.4	27.4	22.5	0.1
0.3	0.118	35.5	36.9	45.6	50.1	67.6	70.3	93.0	96.9	0.3
0.5	0.197	70.2	73.2	98.4	102.7	137.1	143.1	189	198	0.5
0.7	0.2756	113	123	158	165	220	238	303	319	0.7
1.0	0.3937	189	199	264	276	368	379	507	534	1.0
1.25	0.4921	261	273	366	383	509	536	701	740	1.25
1.5	0.5904	340	357	476	501	665	698	914	965	1.5
1.75	0.6889	426	447	599	627	832	874	1140	1210	1.75
2.0	0.7873	518	545	728	766	1010	1070	1400	1470	2.0
2.5	0.9840	721	759	1010	1060	1410	1485	1940	2150	2.5

Formulae prepared for more general purposes

$$\frac{4K\rho}{\pi d^2(d+2t)^2} = r \times 10^9$$

$$d^2(d+2t)^2 = \frac{4K\rho}{\pi r \times 10^9}$$

$$d(d+2t) = \sqrt{\frac{4\rho}{\pi \times 10^9}} \times \sqrt{\frac{K}{r}}$$

$$= \sqrt{\frac{4 \times 10^{-9}}{3.14}} \times \sqrt{\rho} \times \sqrt{\frac{K}{r}}$$

$$= \sqrt{12.73 \times 10^{-10}} \times \sqrt{\rho} \times \sqrt{\frac{K}{r}}$$

$$= 3.568 \times 10^{-5} \sqrt{\rho} \sqrt{\frac{K}{r}}$$

$$d^2 + 2td + t^2 = t^2 + 3.568 \times 10^{-5} \sqrt{\rho} \sqrt{\frac{K}{r}}$$

$$d + t = \sqrt{t^2 + 3.568 \times 10^{-5} \sqrt{\rho} \sqrt{\frac{K}{r}}}$$

$$d = -t \pm \sqrt{t^2 + 3.568 \times 10^{-5} \sqrt{\rho} \sqrt{\frac{K}{r}}}$$

This is the most general form.

t is the thickness of insulation on the side in cms.
ρ - - specific res. of the conductor at the temp. required in ohm cm
K - - c.c.
r - - ohms

For Copper $\rho = \frac{1850}{1760} = 1.05 \times 10^{-6}$ $\quad \sqrt{\rho} = 4.30 \times 10^{-4}$

$3.568 \times 10^{-5} \times 4.30 = 15.35 \times 10^{-4} = 0.00154$ $\quad$ 0.0015

- German silver t^2 is negligible

$$d = -t + 3.568 \times 10^{-2} \sqrt[4]{\frac{K}{r}}$$

$$= -t + 0.0392 \sqrt[4]{\frac{K}{r}}$$

For german silver $\rho = 2.08 \times 10^{-6}$ $\quad \sqrt{\rho} = 1.4414 \times 10^{-3}$

$3.568 \times 10^{-5} \times 1.4414 = 5.151 \times 10^{-8} = 0.00515$

So that $d = -t \pm \sqrt{\{t^2 + 0.00515 \sqrt{\frac{K}{r}}\}}$

and when t^2 is negligible

$$= -t + 7.177 \times 10^{-2} \sqrt[4]{\frac{K}{r}}$$

$$= -t + 0.0718 \sqrt[4]{\frac{K}{r}}$$

For iron wire $t = 1.25 \times 10^{-2}$ say $\quad \sqrt{\rho}\ 1.1 \times 10^{-3}$

$3.568 \times 10^{-5} \times 1.1 = 4.2748 \times 10^{-5} = 0.00042745$

so that $d = -t \pm \sqrt{\{t^2 + 0.00042745 \sqrt{\frac{K}{r}}\}}$

when t^2 is negligible

$$= -t + 6.54 \times 10^{-2} \sqrt[4]{\frac{K}{r}}$$

$$= -t + 0.0654 \sqrt[4]{\frac{K}{r}}$$

On the winding of a radial Ormilling electromagnet.

The magnet is similar to that described on page 163 preceding record book but has only ½ the breadth.

The quadrants being all in multiple gives $\frac{100}{5} = 20$ volts per slab. The surface of a slab is $6 \times 10 \times 2$ sq. in. = 760 sq. in. As the magnetism is continuously being directed we may allow 0.15 watts per sq. cm. = 1140 watts = 5.7 amperes = 3.5 hrs.

If K be the winding space in c.c.
t - - - thickness of the wire in: in cm.
d - - diameter
ρ - - - ~~specifing~~ hot
r - - total res: in ohms

Then $\frac{K}{(d+t)^2} \times \frac{4\rho}{\pi d^2} = r \times 10^9$

$$\pi(d+t)^2 d^2 = \left(\frac{r \times 10^9}{4K\rho}\right)^{-1} = \frac{4K\rho}{r \times 10^9}$$

$$(d+t)d = \sqrt{\frac{4K\rho}{\pi \times 10 \times 10^9}} = 10^{-4}\sqrt{\frac{4K\rho}{r \times 31.42 \times 10^9}} = 10^{-4}\sqrt{\frac{4K \times 1850}{r \times 31.42}}$$

$$= 10^{-4}\sqrt{235.56 \frac{K}{r}} = 10^{-2}\sqrt{\frac{K}{r}} = 1.53 \times 10^{-3}\sqrt{\frac{K}{r}}$$

$$d^2 + td + \left(\frac{t}{2}\right)^2 = \left(\frac{t}{2}\right)^2 + 1.53 \times 10^{-3} \times \sqrt{\frac{K}{r}}$$

$$d = -\frac{t}{2} \pm \sqrt{\left(\frac{t}{2}\right)^2 + 1.53 \times 10^{-3} \sqrt{\frac{K}{r}}}\}$$

Here $t = 0.02$

$K = 120 \times 0.75 \times 16 \cdot 3g. = 1467.5$ c.c.

$r = 2.67 \quad \therefore \frac{K}{r} = 553.4 \quad \sqrt{} = 23.5 \times 1.53 = 36 \times 10^{-3} = 0.036$ $\quad$ 0.0004 $\quad$ 0.0364

$\sqrt{0.0364} = 0.191 - 0.01 = 0.18$ cm $= 0.072''$ = #15 B.W.G.

which has 500 ft per ℔ = 1100 feet ÷ $\frac{15}{20}$ = 660 turns $\times (0.007'')^2$ = 50.0 sq. in. = 5 layers. ∴ 10 layers of wire = 3750 ampere turns

2.66 × 7.5 lbs. = 20 lbs. of wire on each = 40 lbs. in all.

Result 40 lbs. of #15 B.W.G. wire 0.072" or 20 lbs per slab

Particulars of the winding and average magnetic field in the Edison 120 ~~Cycl~~ volt phonograph motor.

The average number of turns on one block is 1140 and 10 blocks form a complete cycle so that 11400 turns each 3 cms in length or 34200 cms is the total breadth of enclosed area. The diam. is 18 cms or 56.5 circumference 170 turns per min = 2.83 per sec. = 56.5 × 2.83 = 160 cm per sec. and the e.m.f. being 8.8 volts see p. 118 both III

$$f = \frac{8.8 \times 10^8}{1.60 \times 10^{-8} \times 34.2 \times 10^3} = \frac{8.8}{6.71} \times 10^3 = 1.31 \times 10^3 = 13 \text{ Gauss}$$

Calculation of the winding for a Brake bar motor on the Quadripolar plan.

The armature to have an external diam. of 7" (17.8 cm)
" internal diam. 5 3/4" = (14.6 cm), the depth 2" (5.1 cm)
and the breadth 5/8" (1.6 cm)
The velocity to be 1200 revs. per min = 20 per sec
$= 20 \times \pi \times 17.8 = 20 \times 55.9 = 1118$ cm per sec.
The breadth $= 5.2$ in
$\therefore 5.2\text{in} \times 1118 = 50 \times 10^5$

$\therefore n = 5.0 \times 10^5 / 5810 \times 10^3 = 8.60 \times 10^5$

If now we take the average field to be double that in the phonograph field namely 2×13 gauss $= 2600 = 2.6 \times 10^3$

Then $\frac{8.6}{2.6} \times 10^2 = 330$ turns. $= 1320$ turns of wire in all.

With the present phonograph armature with pacinotti teeth, this would represent 4 layers of their present wire 0.034"

The coiling space of the wire on any block is $2 \times 2" \times 3\frac{1}{2} \times \frac{1}{2}" = 7$ cubic in $= 114.8$ c.c. All four in series shall have 50 revs. or 12.5 revs each

$$\therefore d = -\frac{t}{2} + \sqrt{\left(\frac{t}{2}\right)^2 + 0.00153 \sqrt{\frac{114.8}{12.5}}}$$

$$= -0.0[illegible] + \sqrt{\{0.00[illegible] + 0.00153 \times 3.80\}}$$

$$\sqrt{0.00[illegible] + 0.0058}$$

$$\sqrt{0.0060}$$

$$0.077 \text{ cm.}$$

$$= 0.069 \text{ cm} = 0.0275" = \# 22 \text{ BWG. } 0.026"$$

which has 0.18 lbs per ft = 9 lbs of wire.

Taking half the coiling space

$$d = -0.038 + \sqrt{\{0.0002 + 0.00153 \times 2.6\}}$$

$$+ \sqrt{0.0002 + 0.004}$$

$$+ \sqrt{0.00402}$$

$$+ 0.063 \text{ cm}$$

$$0.057 \text{ cm} = 0.023" = \# 24 \text{ BWG}$$

which has 0.069 lbs per ft $\equiv$ 3.45 lbs

23 BWG. has 0.1145 lbs per ft = 5.72 lbs of wire or 1.43 lbs on each limb.
= 520 ft per lb = 7579 = 760 feet. The mean turn is $7\frac{1}{2}$" = Around this wire has diam 0.037" = 54 turns to the layer and 1200 turns = 22 layers. = 0.81"

Actually wound 17 oz of # 23 wire on each limb to economise space.

On first running this motor on the 21st September, it made 1050 revs. per min: @ 50 volts on M.T. with 8 amperes of which about 1 ampere would be in the field.

The armature wire is # 23 BWG = 0.025" = 625 c.mil = 2500 cm in all = 312 cm in all

Inductance of a triple coil.

August 17th Saturday

Took the following measurements of the inductance in a small coil whose dimensions were as follows:-

Length 11 cms diam 3·8 cet; 1·4 int.

Primary 0·39 m Secondary 130 m Tertiary 4·30 m.

No.	Bridge	Res. ohs	Capacity	Primary	Secondary.	Inductance Henrys	Henries	Mutual		
1	100/m	129·38	0·37	heated	disc.	0·0479	479			
2		436·5	0·248	disc.	heated	0·1083	1083			
3		436·8	0·088	in batty ct.	"	0·0384	384	0·0699 Mut	0·0636	636
4		436·55	0·405	" - - same	-	0·1768	1768	0·0685	0·0623	623
5		129·62	0·905	heated	in batty ct.	0·1173	1173	0·0694	0·0631	631
6		129·62	negative	"	" - - same	—	-			

Particulars concerning the Niagara Falls.

The contour on the American fall is stated to be 1060 feet
" " " " Canadian " " " " 2640 "
" total fall of water is estimated at 265,000 cubic ft per sec.
" fall on the Canadian side 162 ft
" " " " American " 158 "
" velocity of the stream below the cantilever passenger bridge and the first bend of the stream in the rapids was about 23 miles per hour, a log traversing 540 yards in 55 secs. The log was dropped from the centre of the bridge and appeared to take 5 seconds to reach the water, the height of the bridge being stated at 248 feet

---

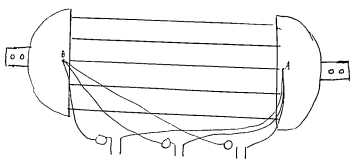
1 cubic foot of water weighs about 62·4 lbs.
So that on the above estimate the weight of water falling per second is 16,536,000 lbs a distance of 160 feet = 2646 million ft-lbs. per second = 4·81 million horse power.

Copy of test of three meters by Mr A. B. Herrick. 28th Nov. 89

1200 ampere R. 0·000333 ω legal

Shunt composed of four strips of special german silver made by Lovell Mfg Co
Each 0·1" thick 6" wide and 52·64" long.
Mounted in massive brass castings and same as 800 ampere shunt
Each shunt carried 300 ampere R = 0·001333 legal ω @ 45°C.
which was temp. obtained after carrying load for one hour.
The drop was then taken & compared with Daniell & Black standards = 0·4 volts
The compensating spools were 46·46 L.ω. @ 70°F.

800 ampere R. 0·0005 ω legal
This shunt was composed of four sheets of special german silver made by Lovell Mfg. Co.
Each 0·0625" thick. 6" wide 67·3125" long.
Mounted in massive brass castings 90% copper 10% tin
Each strip 200 ampere
R. = 0·000125 ω legal @ 38·5°C.
After carrying full load for 1 hour temperature became constant
The final drop test was taken at points A & B. and gave 0·4 volts compared with both standard Daniell & Black.
The three spools each measured 46·46 legal @ 70°F
Connecting wire was so large that its resistance was not appreciable



Each meter deposits 10 milligrammes of zinc for each hour on full load.

The temperatures of the strips carrying 300 ampere each before blackening were

1" × 6" × 67"	Bright	300 ampere	Time 30 mins.	55°C.
" " "	Blackened	"	" 60 "	48°C.

Normal temp. 21°C.

(24)

Calculations for the dimensions of two Edison meters of 800 & 1200 ampere capacity for Mr Beatty & Sons. of Covent Garden London

The large laboratory platinoid shunt is composed of 4 strips each 7 × 22 ¾" (7·58 cms) long 6" (15·2 cms) broad and 0·062" (0·1625 cm) thick and the total res. is 0·001627 ω when all are in series. so that neglecting the res. of the intermediate large pillar, the resistivity is

$$\frac{4 \times 1.627 \times 10^{-3} \times 15.24 \times 0.1625}{4.06 \times 10^{-2}} = 39.7 \times 10^{-6}$$

so that the resistivity of platinoid is practically 40 microhms ω result corroborated by several other measurements.

The rise of temp. in this shunt was very small when 300 ampere passed through it, that is when $3.0 \times 3.0 \times 10^{-6} \times 1.627 \times 10^{-3}$ or 14·5 Watts were generated in it. Its surface being 58 × 2 × 4 × 7 or 3250 sq. cms. i.e. 22·3 sq. cms. per Watt.

All the new Edison meters are designed for a fall of 0·4 volts p.d. ω full load, and if that be taken for the 1200 amp. meter, the energy at full load will be 4·80 Watts and this approximately 10,000 sq. cms in total surface.

If l to the length of ω single meter strip
b - - breadth
t - - thickness } cms
r - - resistance
ρ - - resistivity
s - - surface
Then $2bl = s$ ω constant

$$\frac{l\rho}{bt} = r \quad \text{ω} \quad = \frac{s\rho}{2bt} = \frac{2l^2\rho}{st}$$

$$\therefore lbt = v \text{ the volume of metal} = \frac{st}{2}$$

$$t = \frac{s\rho}{2b^2 r} = \frac{2l^2\rho}{rs}$$

$$v = \frac{s^2\rho}{4b^2 r} = \frac{l^4\rho s}{r}$$

so that $v \propto l^4$

In this case $s = 10{,}000 = 1.0 \times 10^4$
$\rho = 4.0 \times 10^{-6} = 4.0 \times 10^{-5}$
$r = \frac{4}{12{,}000} = \frac{1}{3000} = \frac{1}{3} \times 10^{-3}$

If $l = 100$ $b = 50$ $l^4 = 10000 = 1.0 \times 10^{-4}$ ω 1200 $t = 0.24$ cm $= 0.096"$
$= 80$ $b = 62.5$ $l^4 = 6400 = 6.4 \times 10^{-3}$ ω 765 $t = 0.153$ " $= 0.061"$
$= 120$ $b = 41.75$ $l^4 = 14{,}400 = 1.44 \times 10^{-4}$ ω $v = t = 0.345$ " $= 0.1340"$

At 40° temp. elevation, the radiation will be 0·02356 Watt per sq. cm. × 2 and the convection 100 × 40 × 0·00175 = 7·0
∴ 10000 × 0·047 = 470 + 7 = 477 Watts. when blackened.

With 48·96 in spool & small bottle, the deposit will be 1 mgm. per hour for 120 ampere. and an oxidation of 15 mgms per plate will make a monthly error of 6000 ampere or 8½ hrs. of full load.

With 800 ampères, the energy developed will be $0.4 \times 800 = 320$ Watts at full load, and the resistance will be $\frac{0.4}{800} = \frac{1}{2000} = 0.0005\,\omega = 5.0 \times 10^{-4}$, the area @ 20 sq. cms. per Watt = 6400 sq. cms.

$\therefore t = \frac{2\,l^2 \rho}{r^3}$

If $l = 100$ $b = 32$ $l^2 = 1.0 \times 10^4$ $r = 800$ $t = 0.25$ cm $= 0.100''$.
" $l = 80$ " 40 $l^2 = 6.4 \times 10^3$ $r = 512$ $t = 0.16$ " $= 0.064''$

With 28.96 in bottle circuit 1 mgm is deposited per hour with 200 ampères, so that an error of 5 mgm oxidation per month will represent 400 ampère hours = ½ his full load.

Frequency measurement by the method of Ayrton & Perry

Alternating Dynamo running at 1535 revs per min = 25.7 per second = 2056 alternations or 102.8 ~ per sec.

Joined up an electro magnet on the 100 volt cct, and ran an iron wire between its poles. The alternating current ran through this wire. It was 0.011" = .02798 say 0.028 cms. in diam. The free length when in full vibration was 37½" (95.25 cms) and the tension was 1,500 grammes. The weight of the sonometer wire was 0.07125 grammes per cm. so that from the formula $n = \frac{1}{2l}\sqrt{\frac{f}{m}}$

$l = 95.25$ $2l = 190.5$
$f = 1500 \times 980.2 = 1479000 = 1.47 \times 10^6$ $\frac{f}{m} = \frac{6.335}{3.266} \times 10^8 \sqrt{} = 1.807 \times 10^4$
$m = \cancel{0.07250}\ 0.0045 = 4.5 \times 10^{-3} = \cancel{7.25} \times 10^{-2}$

$1.807 \times 10^4 \div 1.905 \times 10^2 = 9.49 \times 10^1 = 94.9$ complete vibs. per sec.

By means of Helmholtz Resonators, the tone was traced to R_2# D has 72.144 complete periods per sec. $\frac{\cancel{64.5} \times 313.2}{261} = \cancel{76.5}$ 76.5 complete vibs per sec. Taking DT as 8192 single vibrations per sec. $\frac{102}{76.5} = \frac{4}{3}$ = major fourth above or fifth below. It is thus probable that a mistake was made in taking the note as R_2# instead of I_2.

Heat in the magnet of a # 20 dynamo
The E.M.F. of this dynamo being 125 volts and the field magnets having 22ω res. the energy developed at full load in them is $(125)^2/22 = 710$ Watts.
The diameter of one magnet is externally 17¾" = 44.2 cms + circ = 139
length of the field coil is 24" = 60.8 cms
total radiating surface = 60.8 × 139 × 2 = 16,900 and the area per watt = 23.8 say 24 sq. cms.

If the current be 8 ampere and the pressure be 50 volts the energy will be 400 Watt. The radiating coil surface is

$2\pi \times 1\tfrac{1}{2} \times 9.3 + \pi \times 12 \times 10.5$

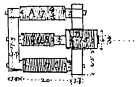
$= 103.4 + 396 = 1430$ sq cms. and allowing 10 watts per sq. cm. ~~for convection~~ = 143 Watts, practically 3 amperes. The total resistance must therefore be $\frac{50}{3} = 16.67\,\Omega$

16⅔ ft of # 19 BWG @ 5.23 lbs per ft = 87.22 lbs in all.
409.29 ft . . = 6820 ft

$\frac{6820 \times 6.48}{23.14} = 1910$ ft on the central core and thus $4910 \div 2 = 2455$ on each outside.
2455 ft = 74880 cms. Round, this wire will have a diam. of 0.080" = 0.2 cms. and there will be 7.5 layers of 89 turns each = 670 turns of mean diam. 7.8 cms. = $670 \times 3.14 \times 7.5 =$
16⅔ ft of # 19 BWG @ 0.913 lbs per ft = 15.2 lbs in all
16⅔ . . . a 170.9 ft . . = 2850 ft

$\frac{2850 \times 6.48}{23.14} = 798$ ft on central core and thus $2850/2 = 1025$ ft on each outside core = 31260 cms. Round, this wire will have a diam. of 0.1145 cms. which means 122 turns and 10 layers = 1220 turns of mean circumference 24.5 cms = 29.900 cm
On the central core there will be 10 layers and $12 \times \frac{1}{0.1145} = 83$ turns = 830 turns

The following are the particulars of this experimental apparatus as at present in use.



Res. of coil A = 7.09 Ω @ 24.°C copper wire 0.026" abt # 22 BWG and offering 2 cms 60 feet per Ω = 4.25 ft = 12960 cms. @ 4.1 mean diam = 129 per turn = 1000 turns diam. of wire covered = 0.041" = 0.103 cms and about 6 layers of 170 turns each.

" " B = 7.37 Ω @ 24.°C same wire = 4.40 ft = 13400 cms = about 1040 turns.

" " D = 1.49 Ω @ 24°C copper wire 0.0240 # 18 B.W.G. about 40 feet per Ω = 205 ft = 6250 cms @ mean diam. of 5 cms = 15.7 per turn = 400 turns = 8 layers of 50 turns and diam. of wire covered = 0.056" = 0.14 cms

" " C = 4.67 Ω @ 24.°C 0.024" diam wire = 2250 = 680 turns

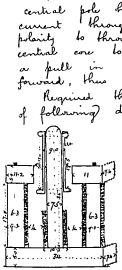
The three field coils were put in series, and a current of 0.51/0.195 or 2.62 ampere passed through them making an exciting power of $2.62\,(650 + 1000 + 1040) = 2.62 \times 2690 = 7050$ ampere turns.

The armature had a current of 1.6/0.195 = 8.21 ampere making an exciting power of $8.21 \times 400 = 3280$ ampere turns.

Under these circumstances, the weight which the armature would lift through a range of 4 cms was 2765 grammes (supported by a wire over a pulley). The work done would thus be 11100 cm. gms. at a stroke. Neglecting at present the effect of a reversal of current in doing work by accelerating the return it would be necessary to repeat the stroke $\frac{746}{1.09}$ or nearly 700 times per sec. to obtain a H.P., and $\frac{1000}{1.09}$ or more than 900 times per sec to realize a Kilowatt.

The two outside field poles are of the same name, and the central pole has the opposite name. The effect of putting the current through the armature is when it strengthens the central polarity to throw a large amount of force from the end of the central core to the outside poles, and these lines of force exerting a pull in the direction of their length carry the armature forward, thus shortening the magnetic circuit.

Required the winding for an apparatus on the same principles of following dimensions.


17.9
10.5
11
7.8
9.3
1.5
2.5
2.5
1.5
2.5
2.5
1.5
2.5
2.5

The armature will have a surface of $\pi \times 13 \times 17.5$ sq. cms = 715 sq. cms and allowing 3 sq. cms per Watt since the armature is in motion, gives 240 Watts. at 50 volts this is about 5 amperes. and the res. of the coil must therefore be 10ω, but as with the intended speed the counter. e.m.f. helped for is considerable, we may commence with the estimate of 5ω.

The ceiling space is

$$\frac{\pi}{4} \times 17.5 \times (13^2 - 9^2)$$
$$= \pi \times 4.375 \times (169 - 81)$$
$$= 3.142 \times 4.375 \times 8.8 \times 10$$
$$= 1210 \text{ c.c.}$$

$$\therefore \quad d = -0.02 + \sqrt{\left\{0.00014 + 0.00153\sqrt{\frac{1210}{5}}\right\}}$$
$$+ \sqrt{\left\{0.00014 + 0.00153\sqrt{242}\right\}}$$
$$+ 0.00153 \times 15.56$$
$$+ 0.0238$$
$$+ \sqrt{0.0242}$$
$$+ 0.156$$
$$= 0.136 \text{ cms} = 0.054''$$

Nearest to this is # 17 B.W.G. 0.058" wire = 0.1466 cm. and covered 0.186

There will thus be $17.5/0.19 = 92$ turns and $\frac{2.0}{0.19} = 11$ layers

= 1012 ampère turns × current.

To obtain seven times the pull of the experimental apparatus we may estimate that seven times the no. of ampère turns will be needed viz 7 × 3280 = 22960 so that on that reckoning 22 amperes will be required to drive it.

The diam. of the mean turn = 11 cms.
diameter. = 34.6 cms.

1012 × 34.6 = 35100 cms. = 1150 feet. × 0.0102 = 11.5 lbs.

5ω × 3.317 = 16.5 lbs. but this is excessive because the wire is 6 layers.

12 lbs of # 17 B.W.G. will be the result.

Measurement of Inductance.

A reel holding 52 lbs or about 1400 feet = 42700 cms. of # 12 B.W.G. S.C.C. black magnet wire diam: 0.109" = .0277 and covered to 0.125" = 0.318 cm. was wound on a reel 25 cms: in diam: and 13.5 cms wide to a Mean diameter of 38.35 cms. a depth of 4.5 cms. It was then measured as follows:-

22. 8. 89. Res. 1000/100 1.4070 including lead 0.1 3.95 ft = 0.0556 ω = .556 kilometres. This wire was not closely wound on the reel. The insertion of a steel bar about 2 cms thick into the centre so as to carry the reel increased the inductance to 0.06650

This wire was then wound to a depth of 3 cms upon a flat wooden board 82 × 15 × 5.5 cms there being 5½ layers. The measurement of the coil (light) wound under these conditions gave the Res: without leads 1.377 $\frac{1000}{100}$ 1.7 ft = 0.0240 ω showing the effect of changing the form of a coil.

In another case the wire on spool had a res: of 1.4425 ω without leads and an inductance of 1.4425 × 0.03888 = 0.0583 ω

In a third case the values were 1.4415 + 1.4415 × 0.03925 = 0.0555 ω

In a fourth case the flat coil removed from its board + slightly distorted gave 1.4448 ω + 1.4448 × 0.01145 = 0.0210 ω

Observations of Sun for obtaining time
22nd August 89 Thursday

At $16^h.\ 19^m.\ 0^s$ Astronomical Clock Time, the observed hour angle was $66°.\ 19'$ or in time $4^h\ 25^m\ 16^s$.
At Gov. noon the equation of time was $2^m.38^s$

Longitude W. $4.\ 56.\ 34$
Hour angle $4.\ 20$
$9.\ 16.\ 34$ = $\frac{9.27 \text{ hour} \times 16}{24}$ = 6.3s subtractive

so that the equation of time was $2^m\ 32^s$ to be added to apparent time.

$4.\ 25.\ 16$
$2.\ 32$
$4.\ 27.\ 48$ True local time.
W of N.Y. $1.\ 00$
$4.\ 28.\ 48$ True N. Y. Mean time

2nd trial. At 16.36.0 Astronomical clock time, the observed hour angle was $64°.\ 4.\ 30'$ or in time $4.\ 32.\ 2$
the apparent elevation 24° the declination 11°.33'.
the equation of time $2.\ 32$
$4.\ 34.\ 34$ Local time
$1.\ 00$
$4.\ 35.\ 34$ N.Y. Mean time

Clock error 36 seconds fast.
The 2nd trial was much more reliable than the first
the magnetic declination appeared to be 7°.30' W.

Record of a Trial made on the 31st Aug: 89
of the effect of a magnetic field on the heart's action

The armature of the # 20 Dynamo was removed, and the fields were charged by the 2 # 10s giving about 210 volt. Three persons, Atwood Lehmann & self were experimented upon. The subject rested on boards with his head well within the polar cavity and with the occipital protuberance downwards supported on a wooden block. The eyes were kept closed, while the sphygmograph tracing was taken of the radial pulse of the left arm. In the middle of the tracing the fields were suddenly excited. The tracings were not very successful partly owing to the influence of the magnetism on the steel needle point, but so far as could be observed there was no effect produced, and no sensation could be recognized.

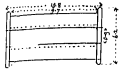
The field was explored by means of the frame mentioned on page 68 Record book VI. The throw in the center of the polar space was 23 that from 1.43×10^{-7} being 107

$$\therefore \mathcal{E} = \frac{23}{107}\left(\frac{5.344 \times 1.43 \times 10^5}{3.77 \times 10^2}\right) = \frac{175.7 \times 10^5}{403.4 \times 10^2} = 436 \quad 43 \text{ Gauss}$$

Inductance Measurements

August 23rd Friday

Took the following measurement with an induction coil without iron core, having four coils and the following dimensions.



P 16 turns coil 4 layers of copper wire covered to 0.0144" = 0.1 on Rm. 056.
S One " 4 " " " " 0.0216" = 0.1 " 0.66.
T One " 9 " " " " 0.032" = 0.08" " 1.67.
a One " 20 " " " " 0.038 = 0.095 " 3307.

No. of obs.	Coil tested	Res: ohms	Cont. on batty cat:	Bridge note	Permittance μ	Inductance Henries	Inductance Kilometer	Mutual Inductance Henries	Mutual Inductance Kilometer	$\frac{L}{R}$ $\frac{L}{R+1}$
1	P	0.492	none	1000/10	0.618	0.000305	3.047			3.05
2	S	0.679	"	"	0.960	0.000652	6.518			6.5
3	T	167.1	"	1000/100	0.410	0.0685	6.850			685
4	a	3205	"	1000/100	0.492	1.626	16.260			16.230
5	a	3307.2	T	1000/100	0.330	1.091	10.910	0.535	5350	
6	"	3307.8	" reversed	"	0.651	2.154	21.540	0.527	5270	~~5320~~ 2660
7	" reversed	3307.9	" ——	"	0.326	1.079	10790	0.547	5470	
8	" ——	3308.7	"	"	0.648	2.144	21.440	0.518	5180	
9	a	3309.8	S	1000/100	0.500	1.655	16.550	0.029	290	
10	——	3310.1	" reversed	"	0.479	1.586	15.860	0.030	300	
11	—— reversed	3311.2	" ——	"	0.500	1.656	16.560	0.030	300	~~300~~ 150
12	—— ——	3311.6	"	"	0.479	1.586	15860	0.030	300	
13	a	3309.8	P	1000/100	0.485	1.606	16.060	0.0165	165	
14	——	3310.2	" reversed	"	0.495	1.639	16.390	0.0165	165	
15	—— reversed	3310.4	" "	"	0.485	1.606	16.060	0.0165	165	~~165~~ 82.5
16	—— ——	3310.6	——	"	0.495	1.639	16.390	0.0165	165	
17	T	167.3	a	1000/100	2.170	03631	3631	0.2948	2.948	
18	" reversed	167.5	" reversed	"	2.170	0.3635	3635	0.295	2.950	~~2.948~~ 1.480
19	T	167.8	S	1000/100	0.443	0.0743	743	0.0058	58.0	
20	"	167.8	S. reversed	"	0.373	0.0626	626	0.00589	59.0	
21	" reversed	168.5	S ——	"	0.443	0.0746	746	0.00614	61.4	~~58.25~~ 5.295
22	——	168.8	" "	"	0.373	0.0630	630	0.0055	55.0	
23	S	0.683	P	1000/10	1.440	0.000983	9.832	0.000331	3.314	
24	"	0.683	" reversed	"	0.455	0.000311	3.109	0.000341	3.410	
25	" reversed	0.684	" ——	"	1.445	0.000985	9.885	0.000336	3.367	~~3.374~~
26	" ——	0.684	"	"	0.455	0.000313	3.113	0.000340	3.405	~~3.334~~
27	P	0.504	S	1000/10	1.270	0.000544	5.440	0.000335	3.353	~~3.353~~ 3.353

Results

Coil	Res:	L Inductance	M: Inductance with P	S	T	a	Kilometer
P	0.504	3.047		3.33			
S	0.683	6.518	3.33		52.95	150	
T	167	685		52.95		2670	
a	3205	16260	82.5	150	2670		

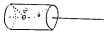
Magnetic Data

Magnetic moment	ml		$L^{\frac{5}{2}} M^{\frac{1}{2}} T^{-1}$
Magnetic mass, strength of pole, quantity of magnetism or magnetic flux of force	$\frac{\mu l d}{r} = m$		$L^{\frac{3}{2}} M^{\frac{1}{2}} T^{-1}$ {current in E.S.units mult. by 1 Sec. = electromagnetic unit}
Magnetic potential, (work or mass) magnetomotive force of solenoid (ampere)		P	$L^{\frac{1}{2}} M^{\frac{1}{2}} T^{-1}$ {EMF in E.S.units mult. by current in E.M.units}
Intensity of magnetization $\frac{ml}{V} = \frac{m}{s}$ or the magnetizing force of a solenoid $\frac{4\pi n c}{l}$ or the intensity of field $\frac{m}{s^2} = H = \mathcal{E}$		H	$L^{-\frac{1}{2}} M^{\frac{1}{2}} T^{-1}$
Reluctance $= \frac{P}{\phi} = R$		R	L^{-1}
Reluctancy ρ $(R = \rho\frac{l}{s})$ $= \frac{H}{B}$		ρ	numeric.

$\mu = 1 + 4\pi K.$

Exciting power = ampere turns/μ = nc.

The magnetic field at any point distant l from a straight conductor carrying a current c is $\mathcal{E}$ $\frac{4\pi c}{l}$ where ϕ is the angle subtended at the point by the conductor. If this total field the component acting parallel to the conductor length is $\frac{c}{l}(\sin\theta_1 + \sin\theta_2)$ where θ_1 and θ_2 are the angles subtended on each side of the perpendicular let fall from the point to the current at l.



(at any point O on the axis or of an cylinder carrying a current uniformly) i.e. a solenoid of current c per unit of length the field will be $2\pi c\,(\cos\theta - \cos\theta)$ so that for an infinite solenoid the field is $H = 4\pi c = \frac{4\pi C}{l}$ and the total flux $= \frac{4\pi C}{l}$ or $\frac{4\pi nt}{l}$ where n is the current and n the total no of turns.

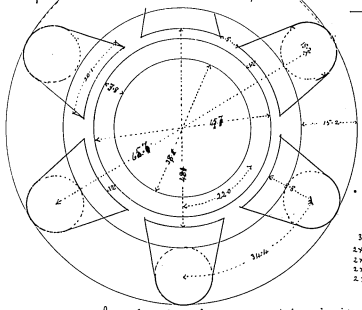
It is thus evident that considering a solenoid without iron core the effect of winding on a cylinder of larger diameter is to increase the total flux for $\frac{d\phi}{dt} = \frac{d\phi}{da} \times \frac{da}{dt} = 2\pi \times \left\{ \frac{4\pi n i}{l} + \frac{4\pi a i}{l} \times \frac{\pi}{4\pi a} \right\}$

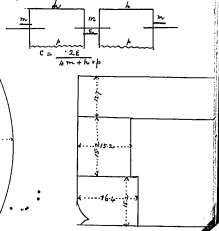
$$= 2\pi \left\{ \frac{4\pi n i}{l} + \frac{i}{4} \right\}$$

for which the turns diminish in number with the radius the area increases with the square of the radius. This applies only however to closed solenoids or where the reluctance of external air is small

Calculation of Induction in the sextipolar transformer

The dimensions of this machine in so far as relates to its magnetic conditions are as follows:—





36·4 − 7·6	=	26·8
2 × 6·4	=	12·8
2 × 15·2	=	30·4
2 × 7·6	=	15·2
2 × 10·	=	20
		105·2

The mean length of the magnetic circuit is in the field magnet allowing 5% reduction = 100 cms.

" " " " " " circuit in the armature = 12 "

" " area of cast iron in the cores is 181·5 sq cms. in each lot.

" " " " " " " " pole . . . 90·7

" " " " " " " " pole . . . 130

" " " " " " " " ring . . . 190

If ρ be the reluctancy of the cast iron. Then the reluctance $r = \rho\left(\frac{26}{190}\right) + \rho\left(\frac{15.2}{90}\right) + \rho\left(\frac{20}{130}\right) = \rho\{0.137 + 0.622 + 0.1538\}$

$= \rho\,(0.913)$

If also ρ_1 be the reluctancy of the wire armature, the reluctance

$= \rho_1 \frac{22}{12.7 \times 3.9} = \rho_1\left(\frac{22}{49.26}\right) = 0.446\,\rho_1$

If also ρ_2 be the reluctancy of the air, then the reluctance of the air

$= \rho_2(0.1456)$

$= 2\rho_2 \times \frac{2}{12.7 \times 10} \cdot \rho_2 \frac{3.4}{12.7} = 0.0189$

$= \rho_2\,(0.0189) = 0.0189$

The {permeability} of cast iron may be taken roughly as 500, and that of the wire armature as 750 for trial values. then

$$R = \frac{0.913}{500} + \frac{0.1456}{750} + 0.0189$$

$$= 0.001826 + 0.000601 + 0.0189$$

$$= 0.02133$$

On each limb of the magnets there are 16 lbs of #23 B.W.G. 0.025"

= 528·5 × 16 = 8460 ft = 257,800 cms. = 1100 "

The internal diam of the core is 15·5 = 46·7 cms. inc.

" external circumference 64·5 "

" mean " 56·6 " = 1·856 ft. nearly

25780 ÷ 56·6 = 4550 turns

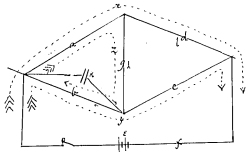
Measured res: of each limb about 160 ω

With 130 volts the current would be 0·812 amp

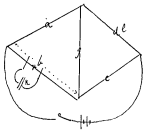
Ampere turns on each limb = 3697 Exciting power = 4650 per limb

= 9300 " pair

vide p. 35

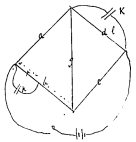


Rimington's amended form



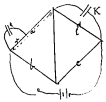
$$l = +kd\left(\frac{r}{b}\right)$$

See Vol. XXX No. 515 Oct. 7. 97 "Electrical Review" London



$$l - Kd^2 = +kd\left(\frac{r}{b}\right)$$

$$l = Kd^2 + kd\left(\frac{r}{b}\right)$$



$$l = Kd^2 - kd\left(\frac{r}{b}\right)$$

Mathematical Treatment of Inductance Measurements.

In the opposite diagram a b c d is a wheatstone bridge, of which d is the arm whose inductance l is to be measured. The other arms having negligible inductance. g is the galvanometer of inductance λ, ε is the testing emf with a res. of f in its circuit, and the currents in the net work are x, y and z.

Then at any moment after closing the key.

(1) $\varepsilon = f(x+y) + a(x+z) + dx + l\frac{dx}{dt}$

(2) $\varepsilon = f(x+y) + b(y-z) + cy$ where q is the charge on condenser k at any instant.

(3) $-\lambda\frac{dz}{dt} = a(x+z) + gz + b(z-y) + \frac{dq}{dt}$

$$\begin{array}{cccc} & (x) & (y) & (z) \\ \left| \begin{array}{c} a+d+f \\ f \\ a \end{array} \right. & \begin{array}{c} f \\ b+c+f \\ -b \end{array} & \begin{array}{c} a \\ -b \\ a+b+g \end{array} \left. \right| & \begin{array}{l} = \varepsilon - l\frac{dx}{dt} \\ = \varepsilon + b\frac{dy}{dt} \\ = -\lambda\frac{dz}{dt} * - b\frac{dy}{dt} \end{array} \end{array}$$

$$\therefore \Delta z = \begin{vmatrix} \varepsilon - l\frac{dx}{dt} & a+d+f & f \\ \varepsilon + b\frac{dy}{dt} & f & b+c+f \\ -b\frac{dy}{dt} - \lambda\frac{dz}{dt} & a & -b \end{vmatrix}$$

where Δ stands for the principal determinant

$$* = \begin{vmatrix} \varepsilon & a+d+f & f \\ \varepsilon & f & b+c+f \\ 0 & a & -b \end{vmatrix} - l\frac{dx}{dt}\begin{vmatrix} f & b+c+f \\ a & -b \end{vmatrix} - b\frac{dy}{dt}\left\{\begin{vmatrix} a+d+f & f \\ a & -b \end{vmatrix} + \begin{vmatrix} a+d+f & f \\ f & b+c+f \end{vmatrix}\right\}$$

$$- \lambda\frac{dz}{dt}\begin{vmatrix} a+d+f & f \\ f & b+c+f \end{vmatrix}$$

$$\Delta z = A - B\frac{dx}{dt} - C\frac{dy}{dt} - D\frac{dz}{dt}$$

Multiplying by dt + integrating between $t = 0$ and $t = T$

$$\Delta\int_0^T z\,dt = A\int_0^T dt - B\int_0^x dx - C\int_0^a dy - D\int_0^z dz$$

The left hand term integral is by adjustment zero, since balance is obtained by the condenser K for both steady and variable currents.

A is identically 0.

the B integral is x the final steady current value

the C - - a - - - condenser charge $= Kax$

- D - - necessarily 0.

$$\therefore \quad 0 = -Bx - CKax \quad \text{or} \quad -B = +CKa.$$

$$\therefore \quad l\,(bf + ab + ac + af) = kbab\left(\frac{x}{a}b + ac + \frac{x}{a}f + \frac{x}{a}bf + cd + df + \frac{x}{a}cf + \frac{x}{a}bf + \frac{x^2}{a^2} - \frac{x}{a}b - \frac{x}{a}f - \frac{x}{a}b\right)$$

$$= kbab\,(ac + cd + df + cf)$$

$d = ma$

$c = mb$

$$l(bf + ab + amb + af) = kbab\,(amb + amb + amf + bmf)$$

$$= kamb\,(ab + amb + af + bf)$$

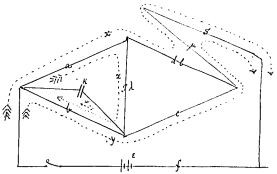
$$\therefore \quad l = kamb$$

$$= kac$$

$$= kbd$$

Maxwell's formula.

Rimington has shewn that if with an unadjustable condenser, K the balance be obtained by throwing k as a shunt round a portion r of the res: b, then $l = kd\left(\frac{r}{b}\right)$



Mathematical Treatment of Mutual Inductance measurement.

With the same notation as on the previous page, let s be a coil having a self inductance of s and a mutual inductance of μ. Then at any instant after closing the battery circuit we have.

$$\varepsilon = f(x+y) + a(x+z) + dx + (l \pm \mu)\frac{dx}{dt} + (s \pm \mu)\frac{d(x+y)}{dt} \qquad (1)$$

$$\varepsilon = f(x+y) + b(y-z-\frac{dy}{dt}) + cy + s\frac{d(x+y)}{dt} \pm \mu\frac{dx}{dt} \qquad (2)$$

$$-\lambda\frac{dz}{dt} = a(x+z) + gz + b(z-y+\frac{dy}{dt}) \qquad (3)$$

From these equations we obtain a determinant for x y z

$$\begin{matrix} a+d+f & f & a & = & \varepsilon - \frac{dx}{dt}(l \pm \mu + s) - \frac{dy}{dt}(s \pm \mu) \\ f & b+c+f & -b & = & \varepsilon - \frac{dx}{dt}(s \pm \mu) - s\frac{dy}{dt} + b\frac{dy}{dt} \\ a & -b & a+b+g & = & -b\frac{dy}{dt} - \lambda\frac{dz}{dt} \end{matrix}$$

so that

$$\Delta z = \begin{vmatrix} \varepsilon - \frac{dx}{dt}(l \pm \mu + s) & -\frac{dy}{dt}(s \pm \mu) & a+d+f & f \\ \varepsilon - \frac{dx}{dt}(s \pm \mu) & -s\frac{dy}{dt} + b\frac{dy}{dt} & f & b+c+f \\ -b\frac{dy}{dt} & -\lambda\frac{dz}{dt} & a & -b \end{vmatrix}$$

$$\therefore \Delta z = \begin{vmatrix} \varepsilon & a+d+f & f \\ \varepsilon & f & b+c+f \\ 0 & a & -b \end{vmatrix} + \frac{dx}{dt}\left\{-(l \pm \mu + s)\begin{vmatrix} f & b+c+f \\ a & -b \end{vmatrix} + (s \pm \mu)\begin{vmatrix} a+d+f & f \\ a & -b \end{vmatrix}\right\}$$

$$+ \frac{dy}{dt}\left\{-(s \pm \mu)\begin{vmatrix} f & b+c+f \\ a & -b \end{vmatrix} + s\begin{vmatrix} a+d+f & f \\ a & -b \end{vmatrix}\right\} + b\frac{dy}{dt}\left\{+\begin{vmatrix} a+d+f & f \\ a & -b \end{vmatrix} + \begin{vmatrix} a+d+f & f \\ f & b+c+f \end{vmatrix}\right\}$$

$$- \lambda\frac{dz}{dt}\begin{vmatrix} a+d+f & f \\ f & b+c+f \end{vmatrix}$$

$$\Delta z = A + B\frac{dx}{dt} + C\frac{dy}{dt} - D\frac{dy}{dt} - E\frac{dz}{dt}$$ multiplying by dt and integrating between $t=T$, $t=0$

$$\Delta z\int_0^T dt = A\int_0^T dt + B\int_0^x dx + C\int_0^y dy - D\int_0^y dy - E\int_0^z dz$$

Here the left hand term integral is adjusted to zero.

A is identically 0

the B term integral is x the final current in a and d

" C " " " y " " " " b " c

" D " " " q " " " charge in condenser K = by K

" E " " " 0 " " " "

so that $0 = Bx + Cy - D$ by k but $y = \frac{ax}{b}$

$$0 = Bbx + aCx - Dabxk$$

$$\therefore \quad Bb + aC = Dabk.$$

$$\therefore b\left\{-(l \pm \mu + s)\begin{vmatrix} f & b+c+f \\ a & -b \end{vmatrix} + (s \pm \mu)\begin{vmatrix} a+d+f & f \\ a & -b \end{vmatrix}\right\} + a\left\{-(s \pm \mu)\begin{vmatrix} f & b+c+f \\ a & -b \end{vmatrix} + s\begin{vmatrix} a+d+f & f \\ a & -b \end{vmatrix}\right\}$$

$$= ab^2k\left\{\begin{vmatrix} a+d+f & f \\ a & -b \end{vmatrix} + \begin{vmatrix} a+d+f & -f \\ f & b+c+f \end{vmatrix}\right\}$$

Determinants marked (1) and (2) are equal. Expanding and simplifying

$$\pm\mu(a+b) + lb = abck$$

whence $\mu = \pm\frac{n}{n+1}(bdk + l)$

$$n = \frac{lb}{\mu}$$

continued from page 30.

The total no. of lines of force ϕ in each segment should thus be $\frac{4800}{0.0213} = 1{,}36{,}600$ which represent an induction $\mathfrak{B}$ in the core of $\frac{1{,}36{,}600}{20} = 6850$ . . . . . armature . $\frac{6{,}36{,}600}{13} = 5700$

The external face of one segment of the armature being 24460 sq. cms × 13.0 = 320 sq. cms., makes an average induction of $\frac{4{,}36{,}600}{320} = 1360 = 13.6$ gauss.

The winding consists of 1 block # 18 B+S in the coarse wire 0.040"
5 - # 24 B.W.G. . . fine - 0.022".

There are 120 blocks in the coarse wire set = 20 blocks per segment
- . 240 - - fine - - = 40 . - -

In each coarse wire block there are two parallel wires 3 turns round = 3 effective turns, and there are 40 of these dits. per sector = 120 effective turns
In each fine wire block there is one wire 27 turns round (9 layers of 3 turns) and there are forty such dits. in a sector = 1080 effective turns.
The mean length of each turn effectively running is about 13 so that the mean coarse wire length = 1560 cms
" " fine " " = 14040 cms

The speed at which the machine runs in action is somewhat uncertain but the best estimate taken from repeating gear is 1600 revs. per min = 26.7 revs. per sec at 4.7 π = 394.0 cms per sec (10.3 ft per sec)
The volts in the fine wire set at full speed were 113 in coarse set
92.5 - fine.

From the coarse voltage the average field $= \frac{1.13 \times 10^{10}}{1.56 \times 3.94 \times 10^{6}} = \frac{1.13 \times 10^{4}}{6.145} = 18.4$ Gauss

- - fine - - - - = $\frac{9.25 \times 10^{11}}{1.404 \times 3.94 \times 10^{7}} = \frac{9.25 \times 10^{3}}{5.53} = 16.73$ -

. mean field = 35.13/2 = 17.6 Gauss

With this result we can approximate more closely to the reluctance of the cast iron for the total no. of lines $= 1.673 \times 10^{3} \times 3.20 \times 10^{2} = 5.35 \times 10^{5}$ allowing 10% for leakage = 5.88×10^{5} in the circuit ∴

$R = \left(\frac{5.88 \times 10^{5}}{9.3 \times 10^{3}}\right)^{-1} = 0.0159$ of this the air was taken 6 bc 0.0189 showing that there is an excessive error in the air space res. or a defect in the exciting power calculation.

Problem. Required the determination of dimensions arrangement and parts of a Continuous Current transformer operating between 1000 and 20 volts pressure, the H.P. delivered to be 20. = 15000 watts.

First for simplicity we will take two gramme armatures running side by side in the same field, and four poles. the peripheral velocity not to exceed 600 ft per sec. 2000 cms. per sec. For 15 kilowatts delivered, at 20 volts M.T. = 750 amperes.
In the experimental transformer the power delivered was 5 kilowatts. and the diam. of the ring was 18", for 15 kilowatts we may take the ring to be say 30" = 76 cms.
Maintaining the same proportion of the interior diam of the ring = 25" = 63.5 cms and the thickness of the ring = 2.5" = 6.35 cms
Since however this becomes a very large machine, it will be better to reduce the output slightly and make the exterior of the ring $\frac{4}{3} \times 18" = 24"$ (61 cms) external diam and $\frac{4}{3} \times 15 = 20"$ (50.8 cms) internal diam, and simply make the output with those dimensions as great as possible
The velocity with a diam. of 75.4" or 191.6 cms = 10.414 revs per sec = 626.4 per

Inductance Measurements

August 26th Monday).

Measurement made with induction coil having core of iron wire.

Diam: of rubber flanges 10 cms. of coil proper 9.2. length 6.3 cms (between flanges 5.2 cms) Diam of iron core about 1.6 cms. Short leads

No. of obs.	Ratio	Temp. B.	Res: obs.	Capacity	KBD	Kilometer	Difference	Mutual Inductance	Kilometer	
1	1000/100	25.5°	6.085	1.455	0.08854	885.4				
2	1000/100		73.03	14.565	0.3331	3336				
3	"		71.77	2.80	0.2010	2010	1326	0.12205	12205	

Similar measurements with a small phosphor box of fine coils

No. of Obs.	Bridge Ratio	Temp B	Res: obs	Capacity	KBD Secohms	Kilometer	Total all non cores Res:	Res: Diff.	KBD Secohms	Kilometer
1	1000/100	25.5°	0.248	0.30	0.00007424	0.7424				
2	1000/100		0.2431	0.275	0.00007328	0.7328	1.257	0.294	0.00036695	3.695
3			0.2426	0.275	0.00007326	0.673	sum = 1.3025			Sum 3.722
4			0.2775	0.287	0.00007964	0.796	Leads = 0.078			
5			0.2737	0.287	0.00007852	0.785	L to be deducted			
					0.7322					

3rd Ann. induction coil, braided length 23.6 cms, diam 3.4, iron wire core 1.3 diam

No. of obs	Bridge Ratio	Temp B	Res: obs	Capacity	KBD	Secohms	Kilometer	Difference	Mutual Inductance	Kilometer
1	1000/100		0.056	2.100	98.95	0.00988	98.98			
2	1000/100		139.36	4.265	574.200	0.57442	5742			
3	"		139.34	2.515	489.800	0.4898	4898	1044	0.0449	449
4	"		139.35	5.000	696.750	0.69675	6967.5	1025.5	0.0932	932 } 900

4th Train communication system low induction coil.

No. of obs.	Bridge Ratio	T. B	Res: obs	Permittance	KBD	Secohms	Kilometer	Difference	Mutual Secohms	Kilometer
1	1000/100		700.9	1.408	987×10^{-6}	0.0987	98.70			
2	1000/100		3.952	0.745	2.969×10^{-6}	0.0003	29.67			
3	" "		3.952	4.690	18.67×10^{-6}	0.0187	186.7	157.03	0.0155	155.5
4	1000/100		705.0	1.095	772×10^{-6}	0.772	7720	2150	0.0195	195.4

5th Station induction coil.

No. obs.	Bridge Ratio	T.B.	Res: obs	Permittance	KBD	Secohms	Kilometer	Diff.	Mutual Secohms	Inds: Kilometer
1	1000/100		30.866	0.633	19.54×10^{-6}	0.1954	1954			
2	"		30.866	alt o Cell Res	0	0	0	2000 alt		1960?
3	"		31.72	0.638	19.38×10^{-6}	0.1938	1938			
4	"		31.72	1.335	42.35	0.42.35	4235	2297	0.2274	2274

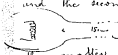
6½ Single coil braided and with iron wire core. length 8.2 diam 6.3
7th - - - papered 4.0 3.5

No. of obs.	Bridge Ratio	Res: obs	Permittance	KBD	Inductance Secohms	Inductance Kilometer	Leads	Res. @ 20°C	Time Constant
1 th	1000/100	6.990	0.557	3.593	0.0359	389	0.07	6.92	0.00582
2 th	T.B. 25°C	7.716	2.031	15.670	0.1567	1567		7.646	0.0205

Electrical Radiance Experiment.

August 27th Tuesday.

Tried to ascertain whether with the aid of ultraviolet rays, any distinct sparking distance could be detected with 100 volts pressure. Arranged the sparks micrometer with its points in close proximity, and illuminated them with a lamp having a quartz window on the plan described and illustrated in the preceding record book page 104. The two such lamps were used the first of 50 c.p. and the second of 16 c.p. spiral carbon and the tube projected 15 mm from the head of the bulb as shown.



No results were obtained with 100 volts although the medium is by no means definitely decided. With 110 + 135 = 245 volts however some rough results were obtained indicating that there is a definite (but scarcely visible) sparking distance for that pressure and that it is assisted by ultraviolet rays. No more than this could be determined before the two lamps had been successively destroyed by over pressure.

Phonograph Potash Battery Test

Observer K Lehmann.

Compared two phonograph potash cells in series, with one Leclanché cell by working them alternately five mins: at a time through 20 platinoid wire, a clock changing the contacts automatically.

Particulars KHO cells.

Glass cell 8 diam (out). Total height 15 cms

Cu Peroxide plate length 12 Breadth 4·5 Thickness 0·8

Zinc rod. " 11 diam. 2·0

Leclanché cell

Glass cell height 15·5 Diam 12

Zinc rod length 16·7 " 0·9

Carbon prism pot " 12·8 " 8

Carbon " Breadth 4·6 Thickness 1·2

Weight of zincs in KHO cells before start (after amalgamating) and drying No 1 239.64 No. 244.2.55

Test commenced 16th Aug. 10 o'clock. continued uninterrupted till 22nd Aug. 8 o'clock 192 hours, by which ~~both~~ both KHO cells exhausted.

The Leclanché cell was practically exhausted after 10 hours.

The weight of the KHO zincs after drying was No 1/179·8 No 2/179·9

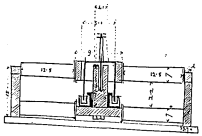
Total loss. 123·49 grammes.

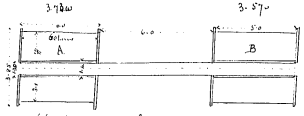
Total calculated output in coulombs from curve sheet in book = 364700 which represents 423.57 grammes so that the observed and calculated zinc consumption practically coincide.

The solution of KHO was of sp. g. 1·20 (NaHO strength)

The sounder contacts were reversed every 12 hours to make sure that the test was fair. That is to say the ~~by~~ contact battery was made the bottom contact battery and vice versa.

Made a rough measurement of the amount of current necessary to practically operate a motor of drum type shown on the opposite page. With 11 ampères through the armature and about 3 amp through the fields in parallel = 0.75 through each magnet the torque was roughly 3 grammes weight at periphery, friction rendering it very difficult to measure more accurately so that if the strength of average field = $\frac{p}{2l}$ = $\frac{3 \times 980 \times 4 \times 33}{1.1 \times 9.5}$ 667 = 6.67 gauss





18 layers × 80 turns = 660 turns on each.
Mean diam = $\frac{3.85+1.80}{2}$, 4.55, 2.28 cms
= 1.434 π cms of wire on each spool. 145 gr. 1.720 cms
wire 1.33 B.W.G. 0.035" = 0.083 cms
150 gr of this wire has resist of 2.64Ω

Inductance Measurements.

Aug. 28th Wednesday.

Measurement of double coil.

No. of Obs.	Bridge Ratio	Res. Std.	Balpy	K.B.D.	Inductance Seckms	Kilometres	Difference	Mutual Seckms	Inductance Kilometres	Mean	Mutual Ind. Kilometres
1	10000/100	3.7444 A	0.927	3.471	0.0347	347.1					
2	TB 213.5 C	3.583 B	0.971	3.48	0.0348	348.					
3	B A_{11}	3.587	0.794	2.849			0.631	0.006246	62.46		
4	B A_{21}	3.587	1.172	4.204			0.724	0.007168	71.68	67.07	
5	A B_{12}	3.664	0.777	2.847			0.624	0.006178	61.78	66.3	
6	A B_{22}	3.664	1.141	4.180			0.700	0.006930	69.30	65.54	

Further measurements were then taken to find the influence of magnetic stress on the core upon the inductance.

1st When B coil tested for inductance. A open. Balpy for balance 0.967
A short circuited by wire . . 0.955

This clear difference of about 1.3% less inductance in B, when the A coil short circuited is perhaps due to the reaction on the core of induced currents in A following those in B by $\frac{\pi}{2}$.

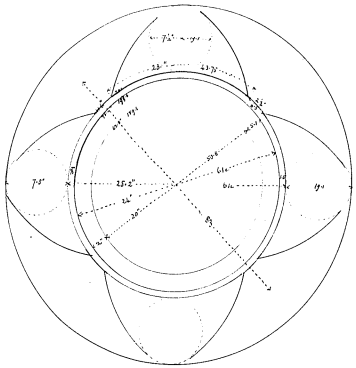
2nd When B coil tested and A magnetized by dynamo current.
The magnetizing current was approximately $\frac{110}{270}$; $\frac{110}{60}$ or 0.407 + 1.83 amp

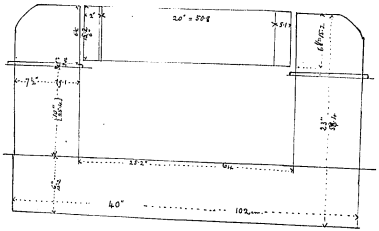
No. of Obs.	Bridge Ratio	Res. Std	Balpy	K.B.D	B Inductance Seckms	Kilometres	A coil	Res. in coil with 110 volts	Current in A	% Red. in Inductance
1	10000/100	3.6030	0.953	3.43	0.0343	34.3	open	∞	amperes.	
2			0.958	3.451	0.0345	34.5	open but touching	270	0.407	
3			0.952	3.430	0.0343	34.3	open	∞		
4			0.832	2.998	0.0300	30.0	closed	60	+ 1.83	12.75%
5			0.936	3.373	0.0337	33.7	open	∞		
6			0.840	3.026	0.0303	30.3	closed (reversed)	60	−1.83	12.18%
7			0.940	3.387	0.0339	33.9	open	∞		

To examine this effect more closely repeated the measurements with the 1st coil between the pole of the large electro magnet in such a way that the iron wire core joined them across. Fig.

No. of Obs.	Bridge Ratio	Res. std. including leads	Balpy	K.B.D	Inductance Seckms	Kilometres	Condition	Current in coil with mag. amperes	Lamps in box
1	10000/100	9.2720	0.426	3.950	0.0395	395.	free in air		
		9.262	1.217	11.270	0.1127	1127	between pole	0	0
		——	.336	3.112	0.0311	311.	"		1
		"	.190	1.760	0.0176	176	"		2
	9.233		.134	1.237	0.0124	124	"		3
		——	.115	1.062	0.0106	106	"		4
		——	.108	0.997	0.00997	997	"		7
		——	.105	0.969	0.00969	96.9	"		8
		——	.095	0.8772	0.00877	87.7	free in air (low mag.)	20	60
							free in air (low mag.)	0	

From this it would appear that the inductance of a coil whose iron core is nearly saturated with magnetism is only 10% greater than when that core is entirely removed. In this instance the inductance was 4.5 times as great with the core in air as without it





With the dimensions shewn, the length of one sector is 147·9 cms external on arc, or 148 cm practically.

The magnetic path is made up as follows.

In each limb mean length 27·9 mean area $\frac{286.5}{2}$ $\quad \frac{L}{A} = \frac{27.9}{143.3} = 0.195$

The conductancy may be estimated at 500

In the base the mean length is 60 cms. and the area 290. So that $\quad \frac{L}{A} = \frac{60}{290} = 0.207$

In the armature the mean length is 22 cms and the area 91 sq. cms. $\quad \frac{L}{A} = \frac{22}{91} = 0.242$

In the poles the mean length is abt 15 cms and the area 200 sq. cms. $\quad \frac{L}{A} = \frac{15}{200} = 0.075$

In the air the mean distance is 1·5 cms. and the area 22 sq. cms × 15·2 = 334 sq cms $\quad \frac{L}{A} = \frac{1.5}{334} = 0.00449$

The total reluctances may thus be taken as

$$2(0.00449) + \frac{2(0.075) + 2(0.195) + 0.207}{500} + \frac{0.242}{700}$$

$$0.00898 + \frac{0.150 + 0.390 + 0.207}{500} + \frac{0.242}{700}$$

$$0.00898 + \frac{0.747}{500} + \frac{0.242}{700} = 0.009 + 0.00015 + 0.00035$$

$$= 0.0109$$

The field winding is determined by the heat of the field. It is proposed to charge the magnets from the secondary circuit and the surface of each coil will be about 29 π × 25 = 1806 sq cms allowing 20 sq. cms per Watt = 90 Watts per magnet, limit and at 20 volts = 4·5 amperes, and the res. will thus be 4·44 ω

The coiling space may be taken as 3/16" = 1·9 cm. so that it becomes

$$\cancel{\frac{\pi}{4}(29.0^2 - 4.44\pi)} \quad \frac{\pi}{4}(22.9^2 - 19.1^2) = 125.3 \text{ sq cms} \times 25 = 3130 \text{ c.c.}$$

$$d = -\frac{L}{2} + \sqrt{\left\{\frac{L^2}{4} + 0.00153\sqrt{\frac{3130}{4.44}}\right\}} = -0.008 + \sqrt{(0.0002 + 0.0153 \times 26.5)}$$

$$+ \sqrt{0.0002 + 0.405}$$

$$= -0.008 + \sqrt{.40855}$$

$$= -0.008 + 0.2014$$

$$= -0.1934 \text{ cm.} = 0.076" = \#15 \text{ B.W.G.}$$

This wire has 502 ft per ω + weighs 7.88 lbs per ω = 2230. in all - 35 lbs. for all per magnet

When covered, this wire will have a diameter of 0.072 + 0.008 = 0.080" = #13 so that there will be 125 turns to the layer, and in 1·9 cms there will be 9·36 layers, say 9 = 1125 turns in all the mean turn having a diam: of 21 cms = 66 cms circ: = 7 ft. 2·40 cms = 1860 feet = 3·7 ω with 10 layers = 1250 turns = 82500 " = 2070 " = 4·44 = 32·5 lbs and the number of ampere turns on each sector = 1250 × 4·5 = 5625

" " " " " " " pair of turns = 11250

" " exciting power for each pair 4π nc = 14,140

so that the total number of lines $\varphi = \frac{14,140}{0.0109} = 1297,000$

the induction $\mathfrak{B}$ in the cores is $\frac{1,300,000}{45.45 \times 2} = 14$ Gauss.

of this 1300,000 we may assume 10% 286 to be lost by leakage leaving 1170,000 available. The whole surface of one sector of the ring at the periphery is 50 × 15·2 = 760 sq. cms, so that the average field = $\frac{1170,000}{760}$ = 1540 or 15Ω Gauss

The peripheral velocity being 2000 cms per sec., and the length of one turn 155 cms we have $n = 1000 \times 10^8 + (2.0 \times 1.55 \times 1.5 \times 10^7) = 10 \times 10^8 + 4.65 \times 10^7 = 14.65 \times 10^7$

$= 20 \times 10^8 + (1.5 \times 1.55 \times 1.5 \times 10^7) = 20 \times 10^8 + 4.65 \times 10^7 = 24.65 \times 10^7$

So that the turns per sector must be $\frac{1465}{2210}$ + $\frac{50}{1434}$ respectively

= 2·25 + 1·15 say.

To integrate the last term $\frac{t}{r}\int_0^{2\pi}\frac{d\theta}{(a+b\cos\theta)^{\frac{1}{2}}}$

Let $= \frac{d\theta}{(a+b\cos\theta)^{\frac{1}{2}}} = \frac{d\theta}{\left\{(a+b)\cos^2\frac{\theta}{2}+(a-b)\sin^2\frac{\theta}{2}\right\}^{\frac{1}{2}}}$

$= \frac{\cos^2\frac{\theta}{2}\,d\theta}{\left\{(a+b)+(a-b)\tan^2\frac{\theta}{2}\right\}^{\frac{1}{2}}} = \frac{\sec^2\frac{\theta}{2}\,d\theta}{\left\{(a+b)+(a-b)\tan^2\frac{\theta}{2}\right\}^{\frac{1}{2}}}$

Let $\tan\frac{\theta}{2} = z$

$\frac{1}{2}\sec^2\frac{\theta}{2}\,d\theta = dz$

$\sec^2\frac{\theta}{2} = 2dz/1+z^2$

$\sec\frac{\theta}{2} = \sqrt{1+z^2}$

$\sec^2\frac{\theta}{2} = (1+z^2)^{\frac{1}{2}}$ $\quad d\theta = \frac{2dz}{1+z^2}$

$= \frac{(1+z^2)^{\frac{1}{2}}\times\frac{2dz}{1+z^2}}{\left\{(a+b)+(a-b)z^2\right\}^{\frac{1}{2}}} = \frac{2(1+z^2)^{\frac{1}{2}}\,dz}{\left\{(a-b)(1+z^2)+2b\right\}^{\frac{1}{2}}} = \frac{2(1+z^2)^{\frac{1}{2}}\,dz}{\left\{(1+z^2)(a-b)+2b\right\}^{\frac{1}{2}}} = \frac{2dz}{(1+z^2)\sqrt{a+b+\frac{2b}{z^2}}}$

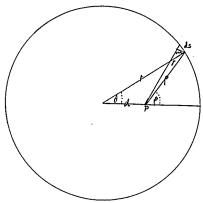
Let $(1+z^2)^{\frac{1}{2}} = y$ $\quad$ Then $\frac{2z}{2y}dz = dy$ $\quad z^2 = y^2-1$ $\quad z = \sqrt{y^2-1}$

$\therefore\ dz = \frac{y\,dy}{y^2-1}$

Let $1+z^2 = y$ $\quad$ Then $2z\,dz = dy$ $\quad dz = \frac{dy}{2z}$

Problem.

The magnetic field produced by an annular current of strength c and radius r at the center is $\frac{2\pi c}{r}$. Required the strength of the field at any point P^r distant d from the center, but within the ring.



$df = \frac{ds\cos\gamma}{\rho^2}$

$\sin\gamma = \frac{d}{\rho}\sin\theta$

$\cos\gamma = \sqrt{\rho^2-d^2\sin^2\theta}$

$\rho^2 = d^2+r^2-2dr\cos\theta$

$ds = r\,d\theta$

Also let $d = pr$

Then $df = \frac{r\,d\theta\sqrt{d^2+r^2-2dr\cos\theta-d^2\sin^2\theta}}{(d^2+r^2-2dr\cos\theta)^{\frac{1}{2}}}$

$= \frac{r^2d\theta\sqrt{p^2+1-2p\cos\theta-p^2\sin^2\theta}}{r^3(p^2+1-2p\cos\theta)^{\frac{1}{2}}}$

$= \frac{d\theta}{r}\frac{(1-p\cos\theta)}{(1-p\cos\theta+p^2)^{\frac{1}{2}}}$

$\therefore\ F = \int df = \int_0^{2\pi}\frac{d\theta}{r}\frac{(1-p\cos\theta)}{(1+p^2-2p\cos\theta)^{\frac{1}{2}}} = \frac{1}{r}\int_0^{2\pi}\frac{k+q\cos\theta}{(a+b\cos\theta)^{\frac{1}{2}}}$ $\quad \left(\begin{array}{l}k=1\\ q=-p\\ a=1+p^2\\ b=-2p\end{array}\right)$

Let $q = sb$ and $k = sa+t$ $\therefore s = \frac{1}{2}$ & $t = \frac{1-p^2}{2}$

Then $F = \frac{1}{r}\int_0^{2\pi}\frac{(sa+sb\cos\theta+t)\,d\theta}{(a+b\cos\theta)(a+b\cos\theta)^{\frac{1}{2}}} = \frac{s}{r}\int_0^{2\pi}\frac{d\theta}{(a+b\cos\theta)^{\frac{1}{2}}} + \frac{t}{r}\int_0^{2\pi}\frac{d\theta}{(a+b\cos\theta)^{\frac{1}{2}}}$

$\qquad\qquad\qquad

Particulars of Machine

No. of Poles	4	
Pole surface	237 x 15"	1422
Diam. Core	73"	1.85
Length "	10"	25.4
Exp. diam. inside excitation	40"	1.13
Armature		
Bot. diam.	26.0"	66
Slot	20"	50.8
Thickness	2"	5.08
Depth	6"	15.2
Gap face	0.75"	1.9
Gap corner	0.75"	0.62
Periphery of iron	75.4"	191.6
" wound on	78.9	130.1
Designed rel. revs per min	626.5	
Peripheral speed fpm for 626 revs	2000.7	
" " " 960 revs	1530	
Velocity revs per sec	10.44	
Peripheral length of outer	19.65"	49.8
" " inner	17.55"	44.6
Inside length " "	15.7"	40
" " core	10.5	27
Calculated magnetic Induction in air gap	9100	
" " core	6550	
Ampere turns in air gap	1.0	
Magnetic flux per pole	2,400,000	
" leakage	1,200,000	
" flux leak to adjacent poles	1,200,000	
" " "	1,200,000	
" " "	1,200,000	
" " "

Solar Observations for Time

2nd September 1889.

Clock Time 9. 07. 00
4. 56. 54
Approx G.M.T. 2. 10
Mag. Decl. 8°.15'.

9. 07. 00
9. 58. 48
Clock error + 8. 12

Hour angle by transit 45°. 24'. 30" = h 3 . m 1 . s 38
a.T. = 8 . 58 . 23

Equation of time @ G.noon = 32.4 s.
Correction for 2 hour 1.6
Equation of time @ obs. 34.0.

M.T. of obs. 8 . 57 . 48
Long. W. of N.Y. 1 . 00
N.Y. M.T. 8 . 58 . 48

2nd trial Mag. Decl. 8°.15'
Clock Time 9. 27. 00
Long 4. 56. 54
Approx G.M.T 2. 24.''

Clock time 9. 27. 00
Calculated 9. 18. 08
Clock error + 9. 00

Hour angle by transit 40°. (less semidiam) 29. 20'
a.T.

Equation of time

2 . 41 . 56
9 . 18 . 04
. 34

M.T. of obs. 9 . 17 . 30
Long. W. of N.Y. 1 . 00
9 . 18 . 30

Sept. 2nd Monday

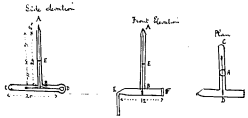
Electrical Radiance.

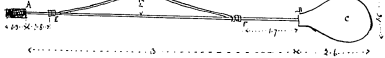
Repeated experiment mentioned on page 35 using pressure of about 170 volts on the lamp, and 200 volts through water resistance tubes on the spark micrometer, but unable to obtain any results at that pressure.

Changed the experimental direction. Took a delicate suspension in glass tubes represented on the opposite page. The intention has been to exhaust this apparatus but owing to leakage round the quartz window, this has not yet been successfully accomplished. It therefore contained air at external pressure

AB. CD & EF are 3 glass tubes at right angle AB being vertical and having sealed into its upper extremity a fine platinum wire 0.002" thick with a small directing steel magnet E 3 cms long + 0.25 broad 0.1 thick, passing through a hole in its centre and then sustains beneath an aluminium suspension of wire with a steel counterpoise at one end and an aluminium vane in the other of dimensions shown.

AB is 35 cms long 2.5 diam ext. BD 23 cms long 2.5 in diam. and EF is 12 cms long + 2.5 diam. EF has an exhaust tube at one end and a quartz window at the other.





The suspension swinging freely and under control of a directing magnet about the level of E, the window was placed opposite to the window of the spiral carbon lamp so that the latter could directly illuminate one face of the vane which was neither polished nor dulled. On examining the position of the vane with a telescope some 3 metres distant it was observed that a slight and slow motion of repulsion took place when the lamp was brought to vivid illumination. That is to say the vane very slightly and slowly retreated. A strip of clear glass inserted between the windows and placed in the path of the beam did not seem to exercise any great effect and two or three plates of ochre and red did not seem to greatly reduce the effect although screens were placed between lamp and apparatus to cut off all extraneous heat influence. A blue glass plate however appeared to extinguish the influence pretty effectually. A water chamber of good construction with clear glass sides and enclosing a liquid vertical station nearly 1 cm thick appeared to entirely cut off the influence although the vessel itself unfilled did not do so. The interposition of a Nichol prism seemed to cut off the influence.

Particulars of Machine

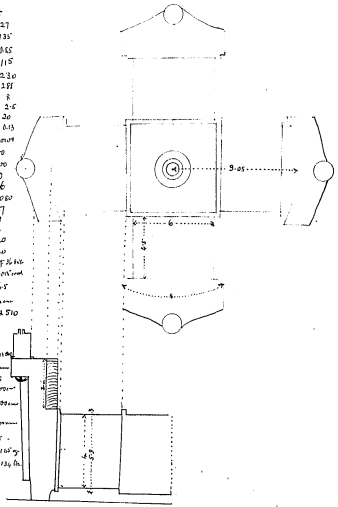
Poles 4

Weight of field 2316 lbs 10500
- armature 474 2115
- (wound)

Layers on limbs 5
Turns per layer 27
Total turns 135
Ampere in field 0.85
Ampere turns 115
A.T. per pair 230
Exciting power 281
Length of pole face 8
Depth 2.5
Area 20
Mean air space 0.13
Mean reluctance 0.0108
Mean flux = 26,700
Mean flux the air 18700
Average field 510
Area of face 36.6
Turns on armature 1080
- per block 27
- layer 9
Layers per block 3
Commutator bars 40
Blocks in armature 40
Size of wire in armature #16 B.W.G.
Diameter 0.054" insulated
Circumference armature 18.5
1 turn per sec = 0.9 cm
Calculated mean field 510
Res. of armature 0.25 Ω
- - field 1.92 Ω
Size of wire in field #19
Diameter 0.042" insulated
Length of field wire 16
field per limb = 3200 cm
Total field wire 420 ft 12,800 cm

Armature wire
27 feet weigh 2.4 grammes
1 - 0.089 -
- 0.002150 g
- 0.000136 lb

Plan of Magnet ½ size



(41)

Data Concerning the Phonograph Motor.

Sept. 3rd 1889.

Two machines were compared similar in all apparent respects except that one had a cast iron armature while that of the other was composed of wrought iron plates.

The test was made with one Chromic acid cell having an emf of 1.916 volts.

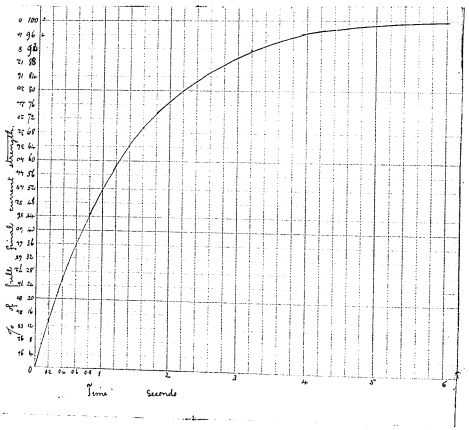
Wrought iron armature (2) and cast iron armature (1) No. Phonograph cylinder

Machine	Condition	Clock sec.	Current in amperes	PD on terminals	Watts	Speed revs. per min	Revs. per sec.	Equivalent revs.	Actual revs.	Commutator corr. factor	Load
Wrought iron armature (2)	Running free	0.573	2.929	1.572	4.62	365	6.08	0.535 w			
	Held	1.120	5.74	1.296	7.44	0	0	0.226 w			
	Armature at Field	0.430	2.205	1.584	3.49	365	6.08	0.718			
		0.980	5.03	1.296	6.52	0	0	0.258	0.255		1.022 watts
	Field cut	0.16	0.82	1.572	1.29	365	6.08	1.92	1.92		Power wasted absorbed at this speed 2.235 watts.
	Held	0.11	0.564	1.296	7.31	0	0	2.20			
	Governing	0.63	3.23	1.576	4.86	216	3.6	0.466			0.488 Eff. @ 365 revs.
		1.12	5.75	1.296	7.45	0	0	0.226			Volt for revs. per min 0.00240
Cast iron armature (1)	Running free	0.365	1.87	1.720	3.22	440	7.33	0.920 w			
	Held	1.08	5.54	1.286	7.12	0	0	0.232 w			
	Armature at Field	0.180	0.92	1.720	1.58	440	7.33	0.87 w			1.425 watts
		1.00	5.13	1.286	6.60	0	0	0.254 w	0.255		Power wasted absorbed at this speed 0.00337
	Field cut	0.180	0.92	1.720	1.58	440	7.33	1.87	1.92		1.366 watts
	Held	0.130	0.667	1.286	0.857	0	0	1.93			
	Governing	0.43	2.205	1.656	3.65	212	3.53	0.75			0.865 Eff. @ 440 revs.
		1.08	5.54	1.286	7.18	0	0	0.232			Volt for revs. per min 0.00337

There are on each limb of the field 5 layers of 27 turns = 135 turns making 105 feet or 3200 cms. of #19 B.W.G. 0.042" diam. The current in the field cut averages about 0.85 amp = 115 ampere turns = exciting power of 1444 on each limb. The polar faces are of 20 sq cm area and the average air space is about 0.13 so that the total reluctance = $\frac{0.26}{20}$ = 0.0108 and a pair of limbs giving 288 magnetic lines gives 26700 lines and the area of one gradient face of the armature is 36.6 sq cms giving an average armature field of 730 or 7.3 gauss. In the armature there are 40 blocks of 10 per sector each having 3 layers of 9 turns = 27 × 10 or 270 turns per sector = 702 linear active wire. One turn per sec = 5.65 cms per sec. peripheral velocity. one turn per min = 0.094 cms per sec. ∴ 702 × 10² × 0.094 × 7.3 × 10⁻⁸ ÷ 10⁸ = volts per rev. per min = 4.52 × 10⁻⁸ = 0.00452 by calculation, everything depending however upon the estimation of the air space, so that the test field = 0.26 gauss for wrought iron and 4.26 gauss for cast iron.

The torque was 0.85 × 1000 grammes = 850 cm gms when 7.1 amperes flow through the armature and 7.1 × 10¹⁰ × 7.0 × 10⁷ × 0.5 × 10³ × 9.0 = 1.64 × 10¹⁰ × 7.0 × 10⁷ the first torque being 8.50 × 10⁵ against 11.6 × 10⁷

Weight of armature 2125 gms wound.
- field 10200 -



Measurement of Inductance of Ore Milling Radial Magnet.

Three of the four quadrants each of 5 magnets in the large radial ore milling machine were tested for their approximate inductance as follows:—

The current passing through the magnet was measured and the discharge received on the ballistic galvanometer with a closed set discharge key. This discharge was compared with that from a condenser.

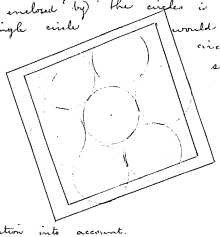
No. of Magnet	Shown 10ω	Current thru magnet amperes	Disch.	Mean C.	Mean Disch	Res. in Galvos.	Q	$\frac{QR}{\pi} = L$	$\frac{L}{R}$	Mean Inductance	Mean $\frac{L}{R}$
								seconds			
1	0.466	0.0932	118				$\frac{120}{123} \times 1.426 \times 10^{-10}$		R = 6.44		
	0.466	0.0932	129								
	0.466	0.0932	127	0.0957	130	55300	1.507×10^{-10}	8.71	1.42		
	0.492	0.0984	134	$= 9.57 \times 10^{-3}$ dec mea		$5.53 \times 10^{4} \times 10^{3}$ 5.53×10^{10}					
	0.492	0.0984	136								
	0.489	0.0978	133								
2	0.494	0.0988	190								
	0.496	0.0912	202								
	0.496	0.0912	190	0.0932	147	55300	$\frac{1.426}{147} \times 147^{10}$	7.66	1.28	8.243	1.38
	0.476	0.0952	96				1.704×10^{-10}				
	0.500	0.100	102								
	0.500	0.100	103								
3	0.507	0.1076	123								
	0.498	0.0996	126								
	0.490	0.0980	128	0.0997	130	55300	$\frac{1.426}{123} \times 130^{10}$ 1.507×10^{-10}	8.358	1.36		
	0.502	0.1004	138								
	0.497	0.0994	135								
	0.496	0.0992	132								
Shunt	EMF C.C.	Charge Measured	Charge abs. mea	Deflection	Res. of Galvos						
Condenser	1.426	1.426	1.426×10^{-10}	123	5290						

At 110 volts the current is 18 ampere = 1980 Watts and the electrokinetic energy in one quadrantal set of magnets is thus $\frac{1.37 \times 1980}{2}$ = $\frac{2720}{2}$ Joules $\frac{27200}{2}$ Megalergs = $\frac{6148}{2}$ therms.

The condition for the aggregation of a perfect strand of the 2nd order is that n=1 centers may form a polygon each vertex of which shall be at 4r from the axis. This polygon is evidently the hexagon formed by the aggregation to one common vertex of six equilateral triangles of side 2r, so that the shortest distance or apothem is $\frac{\sqrt{3}}{2} = \frac{1.73}{2} = 0.865$, a reduction of 13%.

The circumscribing hexagon square perpendicular to the major diameter has a length of side = 6r and an area = $36r^2$.

The area enclosed by the circles is $7\pi r^2 = 21.9912\, r^2$ the equivalent single circle would have a rad. of $\sqrt{7}\, r$ and the circumscribing square would have a side of $2\sqrt{7}\, r$ and an area of $28r^2$, consequently for armature winding purposes neglecting insulation there is a saving of 22%.



Taking insulation into account.

Let the insulation thickness be t. Then the side of the square on the strand is $6(r+t)$ the area $36(r^2+2rt)$. The side of the square on the single wire $2(\sqrt{7}\, r + 2t)$ and the area $28r^2 + 8\sqrt{7}\, rt$.

The difference is $8r^2 + 2\sqrt{15}\, rt$ and with $r = 0.15$ and $t = 0.012$

this is $8 \times 0.0225 + 0.0018 \times 2.15$

$0.20 + 0.038807$

$= 0.2381$

$36r^2 + 72rt = 36\,(0.0225 + 0.0018t)$

$= 36\,(0.02463)$

$= 0.87468$

a reduction of 27%.

Measurement of the Obach Ring Constant

(43)

Observer Lehmann

Sept. 3rd 1889.

A dynamo current was passed through the ring of the Obach and a silver voltameter in series for 300 seconds. The observed deflections made a mean of 0.390 on the tan. scale.

The weight of the silver plate was before	18.4287	anode	15.5130
after	17.7619	cathode	16.1669
	0.6668 loss		0.6539 gain.

Taking the loss = 0.6668

= 596.3 coulombs

= 1988 ampères

= 0.196 on the tangent scale per ampère.

Problem

Required the winding and electromagnetic measurement of a car motor to deliver 7 H.P. (5250 Watts) at full load from a source of 20 volts, the counter emf to be 10 volts and the nominal efficiency 90%. The motor to be of the Gramme ring type with two opposed field magnets like the Fuller Gramme. The yoke to be of cast iron and the pole pieces also, the limbs being of best wrought iron. The armature to have a trial diameter of 12" over all and to have a peripheral velocity of 1200 feet a minute.

In the #20 machine 6 wires each of 48,400 cm carry 400 ampères that is 290400 cm in all or 726 cm. per ampère.

In the #2 M machine 2 wires each of 9025 cm carry 30 ampères that is 18050 cm. in all or 600 cm. per ampère.

Since this motor will have considerable ventilation from free outdoor air we may take 500 cm per ampère. Then it has to receive 525 ampères $\times \frac{10}{9}$ = 525 + 58 or 583 ampères at full load and half of this will be on each side of the armature viz 290 ampères so that 145000 cm. is required. Equivalent to a #00 B.W.G. wire. As this wire cannot be worked it may be divided into a cable of 7 #9 B.W.G. wire each 0.148" diam. and of 21,900 cm each making 153300 cm. in all. Bound these wire would be 0.163" (0.414 cm) The theoretical winding space depth for the seven wires would be 1.15 cm. = 0.28" but practically it will be necessary to allow 0.49" (1.245 cm) in depth and breadth.

The diam. of the armature over all being 12" (29.5 cm) the diam. at the strand center will be 29.23 cm. a circumference of 91.85 cm. which divided by 1.2445 gives 73.8 say 70 turns = 35" on each side half of the ring. If the active breadth be taken at 6" (15.2 cm) the total active length per half ring = 5320 cm.

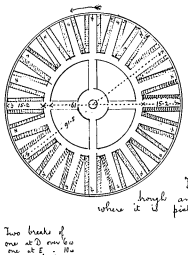
The speed at which this runs through the field is 36000 cm per min = 600 cm per sec. Calling the average field f, since the speed when running light must ~~be~~ provide 20 volts at M.T. we have

$$2.0 \times 10^3 = f \times 5.32 \times 10^2 \times 6.00 \times 10^2 = 31.92 \times 10^4 f$$

$$f = 6.265 \times 10^3 = 6270 = 62.7 \text{ Gauss.},$$

a far stronger field than we can expect to obtain commercially. With a peripheral speed of 1800 feet a min. the field would have to average 41.8 Gauss. at 125 volt the average field in a #20 armature is 32.5 Gauss.

For the field a ring of 18" diam. 14.5" at min center = 36.8 cm. = 115.6 cm. circumference = 92.82 say 93 turns 46 on each half. $46 \times 15.2 = 699.2 \times 10^2$ at 1200 ft per min $f = 46.8$ Gauss. at 1800 ft per min = 32.4 Gauss.



20 magnets each 30" (122 cms) × 5" (12·7) × 2" (5·1) wound with 51 lbs (1418 ft) (43240 cms) of # 12 B.W.G. 0·109" (0·442) diams. Each quadrant of 5 magnets in series, making 6·1 Ω coil. (20°) The exterior brass surface of the drum being 35100 sq. cms. the faces and 13300 on the two sides together a total of 48400. The energy is $3 \times 1/2 \times 110^2 = 56100$ ergs or 56 sq. cms. per Volt. The whole cylinder which is watertight revolves on the axis in a bath of water and emulsifies the ore. The ore is pulled on to the cylinder in the bath and brought up to the left hand top quadrant where it is picked off by a separate magnet.

1st plan. Two breaks of the extra current one at B one by one at E. The two must sparking

2nd plan. Two breaks the first through 6v the second a short circuit on the magnets. A diminished spark occurred at the first break and a bad one at the second, owing to dynamo current.

3rd plan. Same electrical connections but a pair of carbon rods made to flash the spark in the 6v cct after the break bridged the second break. Effectual in operating but very difficult to for exact adjustment.

4th plan. Solenoid in 6v cct. to open it at instant of bridging second break. Too slow.

5th plan. Same solenoid in short circuiting wire round magnet. Too fast.

6th plan a double strip for second break to rest upon. Two breaks as before. B on 3v C on 3v more A the short circuiting strip. D the carbon spark point mechanically operated by the passage of the brush round the 6v strip.

Inductance Measurements

September 6th 1889

Induction coil. Braided. Length 12 Interflange 10·7 Int. Diam 7.15 Ext. 1·7

Diam of wire wire cov 1·4.

No of Ratio	Bridge Ratio	Res. std. T.B. 35°C.	Pri. Coil	Sec. Coil	Condenser	K.B.D.	Inductance Sec. Ohms	Inductance Kilometer	Difference	Mutual Ohms	Inductance Kilometer
	10000/100	0·389	tested	disc.	1·195†	4·648 × 10⁻⁵	0·026648	46·48			
	10000/100	13073	disc	tested	0·675†	8826 × 10⁻⁵	88·26	88·2600			
	"	13075	in bath at	"	0·670†	8740 × 10⁻⁵		874000	0·66	0·60	6000
		"	" rest	"	0·680†		88·90	889000	0·64	0·582	5820
											5910 Mm

Induction coil of iron wire length 10.6 Interflange 9.85. Diam over last layer 3.6. Int. 2·9 No core. 4 layer of 200 turns each, layers separated by paper. Diam of wire 0·011" = 0·0279 covered 0·017" = 0·0143

No of Ratio	Bridge Ratio	Res. std.	Condenser	K.B.D.	Inductance Sec. Ohms	Inductance Kilometer					
	10000/100	412·12	0·003	1236	0·001236	12·36					
	100/100	412·25	0·048	1979	0·001979	19·79					

Induction coil of copper wire length 10.55 Interflange 9.9 3.6. Int. 2.8. No core. 4 layer. Diam wire 0·0375"

No of Ratio	Bridge Ratio	Res. std.	Condenser	K.B.D.	Inductance Sec. Ohms	Inductance Kilometer					
	10000/100	143·29	0·325	4·657	0·04657	4·657					

Radial Ore Milling Machine.

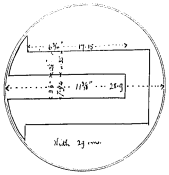
The connections for the radial ore milling machine are as shown on the opposite page. The time constant of five magnets in series is shown on page 42 to be 1·35 seconds. The spark at the commutator on breaking the field at the non-magnetic quadrant is violent. Two breaks across successively increasing resistances did not sufficiently reduce it. The full discharge at 18 amperes through its own resistance amounts to $18 \times 8{\cdot}24/4{\cdot}000 = 2{\cdot}22$ volts. e.m.f. equal to 125 volts charging 200000 microfarads. or 110 volts charging 22.440 †

The energy of the charge would be $\frac{EQ}{2} = \frac{E^2 S}{2}$

$$= \frac{(110 \times 10^8)^2 \times 2{\cdot}244 \times 10^6 \times 10^{-15}}{2} \text{ ergs}$$

$$= 1{\cdot}21 \times 10^{20} \times 1{\cdot}122 \times 10^{-11} = 1{\cdot}357 \times 10^{10} = 1357 \times 10^7 \text{ ergs} = 1357 \text{ Joule.}$$

The plan finally adopted for breaking the spark was to use one insulated bar and to mechanically break the magnet circuit at carbon points outside the machine during the time the brush rested on that bar. This gave a large and powerful spark about 3" long at the carbon points.



Calculation for the winding of two small arc-milling magnets to overhang the large radial machine as collectors.

The diam: of the magnet cylinder is about 29 mm and the ~~length~~ width of the the magnet is also 29 mm: so that the face area of the magnet is approx: $91 \times 30 = 2700$ sq mm. Allowing 20 kg mm to the Watts, this gives 135 Watts which at 50 volts pressure represent 2·7 amperes. so that the res: must be $\frac{50}{2.7} = 18.5\,\omega = 9.25\,\omega$ per limb.

Taking the depth of winding as ½" (1·27 mm) the ceiling space on each limb $= 2 \times (29 + 6.35) \times 17.00 \times 1.27$

$$= 34 \times 35.35 \times 1.27$$

$$= 1530$$

$$d = -\frac{r}{2} + \sqrt{\left\{\frac{r^2}{4} + 0.00153\sqrt{\frac{1530}{9.25}}\right\}}$$

$$= -0.02 + \sqrt{0.00042 + 0.00153\sqrt{165.4}}$$

$$= -0.02 + \sqrt{0.00042 + 0.00153 \times 12.86}$$

$$= -0.02 + \sqrt{0.00042 + 0.0197}$$

$$= -0.02 + \sqrt{0.02001}$$

$$= -0.02 + 0.142$$

$$= 0.122 \text{ cm} = 0.048'' = \#18 \text{ B.W.G.}$$

res: $= 0.0043\,\omega$ per foot $\div$ 1·69 lbs. per ω $\quad 1.69 \times 9.25 = 15.62$ lbs on each limb.
The thickness of the wire covered $= 0.048 + 0.012 = 0.06''$
$= 100$ turns to the layer and 8 layers $= 800$ turns on each limb.
The mean turn has a length of $\frac{70.7 + 72.7}{2} = 71.7$ cms. $= 97360$ mm.
$= 1900$ ft. With 8 layers $= 800$ turns $= 64230$ cms $= 2150$ feet @ 0·00727 lbs per ft $= 15.6$ lbs:

Result therefore 31·2 lbs: of #18 B.W.G. 0·048" with 8 layer of 100 turns on each limb.

Result of Magnet #1 wound with this wire res 19·25 w/o 21°C

Relation of μ to β for different kinds of iron

Jamieson, quoting from Silvanus Thompson gives the relation
wrought iron $\mu = (17000 - \beta) \div 3.5$ for values of β between 16000 & 6000
Aspton Perry) give $\mu = 5221 - 0.3071\beta$ - - - - - 16000 & 10000
For grey cast iron $\mu = 53$ @ 10,000

The Edison Machine Works make Sprague motors of 12½ HP weighing 1450 lbs: and place two upon each large car.

To find the load of greatest commercial efficiency of a motor

Let P be the power supplied to the motor
p - - - " by the "
f - - - wasted - - - in friction
E - - emf assumed constant at the motor terminals.
Then if the motor is run light and takes a current γ,
$E\gamma = f + \gamma^2 r$ where f is the power absorbed + $\gamma^2 r$ is the res: of motor
$f = E\gamma - \gamma^2 r$

At any other load calling for a current c to overcome.

$$Ec = \varepsilon c + c^2 r$$

$$P = (p + f) + h$$

$$p = P - f - h = Ec - E\gamma + \gamma^2 r - c^2 r$$

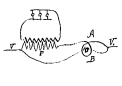
$$\therefore \frac{p}{P} = \frac{Ec - E\gamma + \gamma^2 r - c^2 r}{Ec}$$

$$\therefore \frac{d\left(\frac{p}{P}\right)}{dc} = \frac{Ec(E - 2cr) - E\left(Ec - E\gamma + \gamma^2 r - c^2 r\right)}{E^2 c^2}$$

The energy wasted in heating the armature is equal to the friction assumed constant at all speeds

for max: $\quad E^2 c^2 - 2Ec^2 r = E^2 c^2 - E\gamma E + E\gamma^2 r - Ec^2 r$

$$\therefore -Ec^2 r = -E\gamma E + E\gamma^2 r \quad \therefore c^2 r = E\gamma - \gamma^2 r = f$$



Let A be the coarse coil of the Wattmeter
B . . fine . . . connector
P . . primary . . . connector
r_1 . . . res. including that of A
r_2 . . resistance of B
L_1 . . inductance . .
L_2 . . " . . P and A
e . . p.d. between V and V.
E . . max. value of e.

Then $\varepsilon = E \sin \omega t$ by hypothesis where $\omega = \frac{2\pi}{T}$ and T is the period

$i_1 = A_1 \sin(\omega t - \psi_1)$ where $\psi_1 = \tan^{-1} \omega \frac{L_1}{r_1}$

$i_2 = A_2 \sin(\omega t - \psi_2)$ " $\psi_2 = \tan^{-1} \omega \frac{L_2}{r_2}$

If δ be the reading obtained

$$\delta = \frac{K}{T} \int_0^T i_1 i_2 \, dt$$

$$\delta = \frac{K}{T} A_1 A_2 \int_0^T \sin(\omega t - \psi_1) \sin(\omega t - \psi_2) \, dt$$

$$= \frac{K}{T} A_1 A_2 \int_0^T (\sin \omega t \cos \psi_1 - \cos \omega t \sin \psi_1)(\sin \omega t \cos \psi_2 - \cos \omega t \sin \psi_2) \, dt$$

$(\sin^2 \omega t \cos \psi_1 \cos \psi_2 - \sin \omega t \cos \omega t \cos \psi_1 \sin \psi_2 - \sin \omega t \cos \omega t \sin \psi_1 \cos \psi_2 + \cos^2 \omega t \sin \psi_1 \sin \psi_2)$

$(\sin^2 \omega t + \cos^2 \omega t) \cos \psi_1 \cos \psi_2 - \cos^2 \omega t \cos \psi_1 \cos \psi_2$

$+ (\sin^2 \omega t + \cos^2 \omega t) \sin \psi_1 \sin \psi_2 - \sin^2 \omega t \sin \psi_1 \sin \psi_2$

$- \sin \omega t \cos \omega t \, (\cos \psi_1 \sin \psi_2 + \sin \psi_1 \cos \psi_2)$

$$= \cos \psi_1 \cos \psi_2 + \sin \psi_1 \sin \psi_2 - \cos \psi_1 \cos \psi_2 + \sin^2 \omega t \cos \psi_1 \cos \psi_2 - \sin^2 \omega t \sin \psi_1 \sin \psi_2$$
$$- \sin \omega t \cos \omega t \, (\cos \psi_1 \sin \psi_2 + \sin \psi_1 \cos \psi_2)$$

$$= \sin \psi_1 \sin \psi_2 + \sin^2 \omega t \, (\cos \psi_1 \cos \psi_2 - \sin \psi_1 \sin \psi_2) - \sin \omega t \cos \omega t \, (\sin \psi_1 \cos \psi_2 + \cos \psi_1 \sin \psi_2)$$

$$= \sin \psi_1 \sin \psi_2 + \sin^2 \omega t \cos(\psi_1 + \psi_2) - \sin \omega t \cos \omega t \sin(\psi_1 + \psi_2)$$

$$= \sin \psi_1 \sin \psi_2 + \cos(\psi_1 + \psi_2) - \cos^2 \omega t \cos(\psi_1 + \psi_2) - \sin \omega t \cos \omega t \sin(\psi_1 + \psi_2)$$

$$= \sin \psi_1 \sin \psi_2 + \cos(\psi_1 + \psi_2)(1 - 2 \sin^2 \omega t) + \sin^2 \omega t \cos(\psi_1 + \psi_2) - 2 \sin \omega t \cos \omega t \sin(\psi_1 + \psi_2)$$

$$\sin \psi_1 \sin \psi_2 \quad \overline{\text{or}} \quad \cos(\psi_1 + \psi_2) \cos 2\omega t \quad \overline{\text{or}} \quad \sin 2\omega t \sin(\psi_1 + \psi_2) + \sin^2 \omega t \cos(\psi_1 + \psi_2)$$

$$+ \sin \omega t \cos \omega t \sin(\psi_1 + \psi_2)$$

$$= \sin \psi_1 \sin \psi_2 - \cos(2\omega t - \psi_1 - \psi_2) + \sin^2 \omega t \cos(\psi_1 + \psi_2) + \sin \omega t \cos \omega t \sin(\psi_1 + \psi_2)$$

$$= \frac{\cos(\psi_1 + \psi_2)}{2} + \sin \psi_1 \sin \psi_2 - \cos(2\omega t - \psi_1 - \psi_2) + \frac{2 \sin^2 \omega t \cos(\psi_1 + \psi_2) - \cos(\psi_1 + \psi_2)}{2} + \frac{\sin 2\omega t \sin(\psi_1 + \psi_2)}{2}$$

$$= \frac{\cos(\psi_1 + \psi_2)}{2} + \sin \psi_1 \sin \psi_2 - \cos(2\omega t - \psi_1 - \psi_2) + \frac{\cos 2\omega t \cos(\psi_1 + \psi_2)}{2} + \frac{\sin 2\omega t \sin(\psi_1 + \psi_2)}{2}$$

$$= \frac{\cos(\psi_1 + \psi_2)}{2} + \sin \psi_1 \sin \psi_2 - \frac{\cos(2\omega t - \psi_1 - \psi_2)}{2}$$

$$= \frac{\cos \psi_1 \cos \psi_2 - \sin \psi_1 \sin \psi_2}{2}$$

$$= \frac{\cos(\psi_2 - \psi_1)}{2} - \frac{\cos(2\omega t - \psi_1 - \psi_2)}{2}$$

$$= \frac{K}{2T} A_1 A_2 \int_0^T \cos(\psi_2 - \psi_1) - \cos(2\omega t - \psi_1 - \psi_2) \, dt$$

Alternating Current Converters.

Data collected concerning them from various sources.

If n_1 and n_2 are the numbers of turns of wire in the primary (secondary) circuits respectively of a converter of closed magnetic circuit, the coefficients of self and mutual inductance are in the ratio

$$n_1^2 : n_2^2 : n_1 n_2$$

A good rate of working is 100 ~ per sec.

If the alternations be increased n times the wire may be reduced $\sqrt{n}$ times roughly or the emf rise roughly by that amount.

In an ordinary transformer the wire is said to average in either circuit from 1·5 to 2 ~~feet per~~ volts per foot. The initial current in the primary with the secondary open should not exceed 0·05 amperes.

The induction $\mathfrak{B}$ should not be above 10,000 lines per sq. cm.

A fair average is 7000

Pinnington's method of measuring the power supplied to the primary coil of a transformer by means of a Siemens dynamometer

$$p = K \delta \frac{r_1 (r_2^2 + \omega^2 L_2^2)}{r_2 (r_1 r_2 + \omega^2 L_1 L_2)}$$

(Wattmeter) whose continuous current constant is K, and δ is the deflection:

where r_1 is the ohmic res. of the primary + that of the coarse coil of Wattmeter
r_2 . . . . . ~~secondary~~ fine coil of Wattmeter
L_1 . . inductance . . . primary + that of the coarse coil of Wattmeter
L_2 . . . . . ~~secondary~~ fine coil of Wattmeter.
ω . . $\frac{2\pi}{T}$
δ . . brown reading
K . . constant of the inst. for continuous currents
p . . power absorbed by the primary in Watts including the ~~[illegible]~~ watts

An allowance of 20 sq. cm. per Watt should be given to transformers for the total heat generated therein.

The weight of a transformer varies from 10lbs to 50lbs per HP

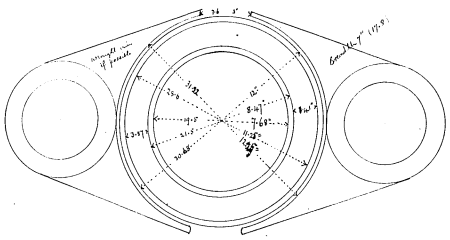
. efficiency of a good transformer is 96% at full output and 90% at 1/4 full output.

For a parallel transformer to be effective in regulation the drop in the secondary at full load should not exceed 1% of the mean secondary and similarly the drop in the primary due to ohmic res. should not exceed 1% of the mean primary emf.

The diam. of the wire should not exceed 250 mils, if greater be required it should be subdivided to avoid creation of vortices.

At 27000 and 100 ~ the hysteresis is given at 3700 ergs per cubic inch per cycle or 37 Watts per cubic decimeter of iron. ~~[illegible]~~

Section of the armature by plane ⊥ axis
scale 1/8" to the cm.
about 1/4 actual size



Particulars of Motor

Dimensions

Length over all	32.6 cm	12.7"
Breadth - -	66.2	25.8"
Length of core	20.3	8"
Diam. - -	11.3	4.4"
Yoke Section	12.1 x 14.7	4.75" x 5.8"

Armature

Breadth of ring	17.8	7"
Diam. over all	32.6	12"
Thickness of winding	2.92	1.15"
Clearance	0.52	0.15"
Thickness of ring	3.57	1.4"
Diam. ring out	28.6	11.25"
" " int	21.5	8.47"
" interior of ring	18	7"
Space between pole pieces	7.6	3"

Weight

28" of core cm. 11.3 x 7.6 = 2.12 lb	
poles estimated	20
22" of weight of 2.92 x 7.8 = 1.14	1.90
field winding	27
armature	50
" cm. 7.6 x 2.92 = 1.14	1.90
Commutator & shaft	17.0
Total	119

Magnetics.

Total flux 2,375,000
Leakage allowed 20%
Useful flux 1,900,000
ϕ in core 11,000 per cm²
ϕ in yoke 6,000 " "
ϕ in armature 11,000 " "

Winding

Armature

E.M.F. 12.8 volts. 0.165
Ewatts on Armat. watts 88
" " " watts 8
Number of Armat. cm each half ring 66
" " " in all 66
cross-section wire

Field

Each core of length of 28 turns wire
ϕ 0.165 Total length 924 Total lb
924 turns 1.3 ohm current 1 amp
depth of winding 1.5
Total wire each field 1.3
Turns in series = 1.3 = 5 amperes
= 3150 ampere turns per limb
= 1.3 amp
= 7850 exciting turns in all
Total reluctance 0.0061 limb

Motor Calculations

continued from page 43.

Taking 2000 ft per min as the peripheral speed of the armature = 9000000 per min or 1500 cm per sec. we may arrange the winding more favourably. With six wires their size must be $\frac{145000}{6}$ = 24,100 nearest to B.W.G. each 0.165" covered 0.180" (0.419 cm) cm 0.457 cm), three wide and two deep = 0.36" or 0.914 cm deep and 0.54" or 1.371 cm wide. The diam. of the drum being 30.48 cm, at the centre of the winding it will be 29.67 cm. and the corresponding surface = 92.99 cm which allows for $\frac{92.99}{2 \times 1.371}$ = 33.9 turns on each side of the whole cylinder each half ring say 33. Then with a breadth of 15.2 cm the average field required to generate 20 volts will be $15.2 \times 33 \times 1500 \times f = 20 \times 10^8$ or $f = 2657$ = 26.57 gauss. The area of the pole-faces, armature half surface will be $\frac{30}{2} \times \pi \times 15.2$ cm = 716 sq. cm so that the total flux must be 716 x 2657 = 1,902,000 usefully employed.

The thickness of the ring may be taken as 0.25 r where $r = \frac{30.48}{2}$ = 0.95 = 14.24 = 7.57 and the internal diameter therefore (22.86) which reduced by 0.95 gives 19.54 as the diam. of the inside winding or circumference of 61.3. This allows the three x 2 turns to lie inside 2 x 3.

The thickness of the iron ring being 3.57 and its length 15 the magnetic area is 1071 sq. cm. Of this some 20% may be allowed for insulation leaving 857 sq. cm for conduction and this represents an induction of 22,000 lines per sq. cm. This is excessive.

Taking the length of the cylinder at 7" (17.8) the average field has to be only $26.57 \times \frac{6}{7}$ = 22.78 gauss and the total flux remains unaltered. The magnetic area has correspondingly increased so that the induction is $\frac{22000 \times 6}{7}$ = 18,800 lines which is not excessive.

Allowing 20% for leakage the total flux to be provided for is 1,902,000 + 475,000 = 2,375,000 lines

Let us assume 12,000 lines per sq. cm. in the magnets. Then the area of the magnet cores must be 200 sq. cm.

The corresponding density in the cast iron may be taken as 6000 which gives 400 sq. cm. As there are two magnetic circuits the cores must have 100 sq. cm. each and the yokes 200. The cast iron pole pieces must also have 500 say. The diameter of the core must therefore be 11.3 cm. = 4.45" say 4.5". The winding depth may be made 1" as a trial value. Then the diam. of the whole magnets overall will be 6½" (16.52). The trial length of the core may also be made 8" (20.3). Then the width of the cast iron yoke will be at least (6½)(16.5) so that at that width the thickness should be $\frac{200}{16.5}$ = 12.1 cm. (4.85")

The reluctances must now be as follows:—

				$\frac{L}{m}$	μ	rel.
In the armature the mean length will be 17.8 cm			area 127 sq. cm.	0.0778	60	0.00233
" "	pole pieces	length	2 x 18	0.22	500	0.000140
		area	180			
" "	cores	length	20.3	0.20	1400	0.000142
		area	100			
" "	yokes	length	½(47.7)	0.119	250	0.000476
		area	200			
" "	clearance	length	2 x 0.52	0.00268	1	0.00268 0.00268
		area	190			
" "	winding	length	2 x 0.92	0.00212	1	0.00212 0.00212
		area	870			
					Total reluctance	0.006161

The required flux is 2,375,000

and $\frac{1.257}{0.006104}\, a.T. = 2.375 \times 10^6$

$$\therefore\ aT = \frac{2.375 \times 10^6 \times 0.6104 \times 10^{-2}}{1.257} = 11530 \text{ on each pair of limbs.}$$

If now we have 3.8 times as many, then the iron will be saturated and where the voltage falls on a heavy load the field will be weakened. Let the a.T be therefore 34660 on each pair or 17320 on each pair of cores. The surface of the cores is 20.3 × 50 = 1000 sq. cms (bet) and with 16 (Watts per sq. cm) 100 Watts may be allowed = 5 amperes at 20 volts = 4 w. in all, 2 w each.

The ceiling space is for one 20.3 × (213.8 − 100.3) = 20.3 × 113.5 = 2304 c.c. The diameter of the wire is thus

$$d = -\frac{t}{2} + \sqrt{\left\{\frac{t^2}{4} + 0.00753\sqrt{\frac{2300}{2}}\right\}}$$

$$= -0.02 + \sqrt{\{0.0004 + 0.00153 \times 38.73\}}$$

$$\sqrt{\{0.0004 + 0.05924\}}$$

$$\sqrt{(0.05964)}$$

$$D\ 24443$$

$$= 0.2244 \text{ cms.} = 0.088'' \quad \text{nearest \# above } 0.095'' \ (\text{\# } 13.\ \text{B.W.G.})$$

with 23.9 lbs. per w. and 47.8 lbs. on each limb.

If all four coils be in series that is have 1w each

$$d = -0.02 + \sqrt{\{0.0004 + 0.00153\sqrt{2300}\}}$$

$$\sqrt{\{0.0004 + 0.0734\}}$$

$$\sqrt{(\ \ 0.0738\ \ )}$$

$$D\ 272$$

$$= 0.252 \text{ cms} \quad 0.100'' \quad \text{nearest \# } 0.095'' \ (\text{\# } 13\ \text{B.W.G.})$$

with 23.9 lbs. per w and 95.6 lbs. on all four limbs together.

The length is 8714 feet and the mean turn has a diameter of 13.9 cms 4.367 cms so that the no. of turns on each limb is $\frac{26660}{4.367} = 610$ and the ampere turns 3050

The res: of the armature will be:—

48 cms per turn + 33 turns = 1584 cms. of 6 #8 wire on each half ring = 264 cms of #8 wire on each half ring = 132 cms of #8 wire equivalent = 4.33 feet × 3.79 × 10^{-4} = 16.4 × 10^{-4} = 0.00164 ohm

9.66 feet of 6 #8 wire = 10 feet of #8 wire = 0.0326 = 32 ohm. 22 = 24 ohm

The drop in the armature at 600 amperes = 10 volts = 6000 Watts.

loss in the field is 5 amperes @ 20 volts say = 100 –

Calculation of electrical efficiency of the system.

			Watts.
Energy delivered at fine wire terminals of transformer @ 14 ampere =			14000
Heat lost in fine wire armature at full load		1570 Watts	
600 4.66	" " coarse " " " " "	2810	
	Waste in transformer armature	4380	
	" " " magnets 174 × 15	2610	
		6990	f Work 33.2
	Waste in motor at full load	6000	
	field magnets	100	
		10744	f. Work 76.7 10740
	1.4# must probably be allowed for friction leaving 18# for use.		less than 5 # 3260

With 100 amp. delivered by transformer = 74 Watts in coarse 20 in fine wire 300 in magnets 400 Watts. in motor full 100 armature 16 . 520 in all out of 2600 the work being only 25%

Table of Observed variations of Specific Gravity with temperature in $ZnSO_4$ solution of 1.11 @ 20°c

Temp:	0°	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	55	60°	65°	70°	75°	80°
Sp. Gr.	1.1140	1.1135	1.1125	1.1115	1.1100	1.1055	1.1070	1.1055	1.1040	1.1015	1.0995	1.0970	1.0940	1.0910	1.0880	1.0850	1.0820
Δ		0.0001	0.0002	0.0002	0.0003	0.0003	0.0003	0.0003	0.0003	0.0005	0.0002	0.0005	0.0006	0.0006	0.0006	0.0006	0.0006
Corrected Sp. Gr.	1.1140	1.1135	1.1125	1.1115	1.1100	1.1055	1.1070	1.1055	1.1040	1.1020	1.0995	1.0970	1.0940	1.0910	1.0880	1.0850	1.0820
Δ		0.0001	0.0002	0.0002	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002	0.0001	0.0005	0.0006	0.0006	0.0006	0.0006	0.0006

0° to 5°	0.0001	0
5° - 15°	0.0002	10
15° - 40°	0.0003	30
40° - 45°	0.0004	40
45° - 55°	0.0005	50
55° - 75°	0.0006	65

Assuming the empirical formula

$$d_t = a + bt + ct^2$$

we have

$$\left.\begin{aligned} d_{1100} &= 1.1140 + 20b + 400c \\ 1.0880 &= 1.1140 + 70b + 4900c \end{aligned}\right\}$$

$$20b + 400c = -0.0014$$
$$70b + 4900c = -0.026$$
$$2b + 20c = -0.00020$$
$$b + 70c = -0.000371$$
$$50c = -0.000171$$
$$c = -0.0000342$$
$$b = -0.000684 + 0.000200$$
$$= -0.000484$$

$$d_t = 1.1140 - 0.000484t - 0.0000034t^2$$

$$d_{15} = 1.1140 - 0.00132 - 0.000034$$
$$- 0.00166$$
$$= 1.11234 \quad 1.110 \text{ against } 1.1125$$

$$d_{30} = 1.1140 - 0.00263 - 0.00036$$
$$- 0.00299$$
$$= 1.1093 \text{ against } 1.110$$

$$d_{50} = 1.1140 - 0.00395 - 0.000378$$
$$- 0.00703$$
$$= 1.107 \text{ against } 1.107$$

$$d_{60} = 1.1140 - 0.00526 - 0.00544$$
$$- 0.01070$$
$$= 1.1033 \text{ against } 1.104$$

$$d_{70} = 1.1140 - 0.00658 - 0.00855$$
$$- 0.0151$$
$$= 1.099 \text{ against } 1.0995$$

$$d_{80} = 1.1140 - 0.00790 - 0.0123$$
$$- 0.0202$$
$$= 1.0938 \text{ against } 1.0940$$

$$d_{90} = 1.1140 - 0.00921 - 0.0171$$
$$- 0.0263$$
$$= 1.0877 \text{ against } 1.088$$

$$d_t = 1.1140 - 0.000484t - 0.0000034t^2$$
$$1.1140 - 0.000484t\,(1 - 2.6t)$$
$$= 1.1140 - 1.316t \times 10^{-4}\,(1 - 2.6t)$$

The weight of the Siemens Altg. Current Dynamo in the Dynamo room is 711 lbs.

In the transformer itself if V and v are the electrical pressures at the primary & secondary terminals we have:

(1) $V = E + c_1 r_1$
(2) $v = \eta - c_2 r_2$
(3) also $V = nv$
(4) and $\frac{n}{1} c_1 = \frac{1}{n} c_2 + f$

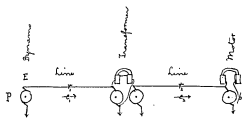
hence (1) $E = V - c_1 r_1$
(2) $\eta = \frac{V}{n} - c_2 r_2$
(4) $c_1(V - c_1 r_1) = \left(\frac{V - c_2 r_2}{n}\right) c_2 + f$
$\therefore f = (c_1 - \frac{c_2}{n})(V - c_1 r_1)$

$$E = \frac{V}{n} - \left(c_1 \frac{r_1}{n} + c_2 r_2\right)$$
neglecting friction & eddies

$$= \frac{V}{n} - c_2\left(r_2 + \frac{r_1}{n^2}\right)$$

also $v = \frac{V}{n} - c_2 \left\{\frac{r_1}{n^2}\left(1 + \frac{f}{c_2 v}\right) + r_2\right\}$ taking friction & eddies into account.

$$= \frac{V}{n} - c_2\left[\frac{E}{n} + \frac{r_1}{n^2}\left\{1 + \frac{f}{c_1(V + c_1 r_1)}\right\}\right]$$



To find the maximum power capable of being yielded by a given value of E we have the relation

$$\frac{dp}{dc_1} = E - 2c_1(r_1 + n^2 r_2)$$

so that $E = 2c_1 r_1 + 2nc_2 r_2$

or $E = 2c_1(r_1 + n^2 r_2)$

$E = 2c_2\left(\frac{r_1}{n} + nr_2\right)$

whence $c_1 = \frac{E}{2(r_1 + n^2 r_2)}$ $\quad c_2 = \frac{E}{2\left(\frac{r_1}{n} + nr_2\right)} = \frac{nE}{2(r_1 + n^2 r_2)}$

assuming that the second line has a negligible resistance. Now if the transformer had been used directly as a motor the maximum power would have been obtained from a current of $\frac{E}{2r_1}$ at an efficiency of 50%. By transforming however besides the extra waste in field magnetism and the second motor friction the maximum power is given by a further current in the ratio of $r_1 : (r_1 + n^2 r_2)$ where n is the coefficient of conversion, with a correspondingly reduced efficiency. For example in the car motor system lately calculated for in this book $n = 50$ $r_1 = 8\,\omega$ and $r_2 = 0.008\,\omega$ so that with $E = 1000$

$c_1 = 18.2$ @ 36.5% efficiency $= 5110$ Watts delt.

while if the transformer had been used as a motor the best value of

$c_1 = 62.5$ @ 48% efficiency $= 29{,}000$ Watts delivered

Efficiency of a Motor cont. from page 45.

With the same notation as on page 45

If P be the power supplied to the motor
" p " " " by " "
" f " " " absorbed by " " in friction (constant at all loads)
" h " " " " " " heat
" m " " " " " " supplying its field.
" γ " " current required to run the motor unloaded
" E " " emf. of the source

Then $E\gamma = m + f + \gamma^2 r$

and by (precisely) similar reasoning to that on page 45

$\frac{p}{P}$ or the efficiency when $c^2 r = m + f = E\gamma - \gamma^2 r$

so that the heat waste in the armature equals the total energy expended in running the motor light.

In the next case let us consider a continuous transformer system consisting of a motor dynamo supplied by an inconstant E.M.F. at machine primary terminals with a constant field and delivering a corresponding supply of low pressure current, through its own armature line and a motor of constant field.

Let E be the electrical pressure at the dynamo end
P " " power electrically taken from the source E
r_1 " " resistance of the line and primary of the transformer
r_2 " " resistance of the second line, the secondary of the transformer and the armature of the motor
f " " power wasted in overcoming the friction of the transformer together with the resistance of eddies
φ " " power wasted in overcoming the friction of the motor both mechanical and magnetic
m " " power constantly consumed in exciting the field of the transformer
μ " " power constantly consumed in exciting the field of the motor (m and μ are not quite constant but are sufficiently nearly constant for practical purposes)
p " " power given out by the motor.

Then $P = p + c_1^2 r_1 + f + m + c_2^2 r_2 + \varphi + \mu$

$= p + c_1^2 r_1 + c_2^2 r_2 + K$

But if ε be the counter emf. of the primary coil of transformer and η " " generated emf of the secondary " "

$\varepsilon c_1 = \eta c_2$ $\quad$ let $\frac{\varepsilon}{\eta} = n$ $\quad$ Then $c_2 = nc_1$

$$P = p + c_1^2 r_1 + n^2 c_1^2 r_2 + K$$

$$\therefore p = Ec_1 - c_1^2(r_1 + n^2 r_2) - K$$

$$\frac{p}{P} = \frac{Ec_1 - c_1^2(r_1 + n^2 r_2) - K}{Ec_1} = \frac{E - c_1(r_1 + n^2 r_2) - \frac{K}{c_1}}{E}$$

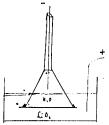
$$\frac{d\left(\frac{p}{P}\right)}{dc_1} = \frac{Ec_1\{E - 2c_1(r_1 + n^2 r_2)\} - E\{Ec_1 - c_1^2(r_1 + n^2 r_2) - K\}}{E^2 c_1^2}$$

for maximum $\quad c_1\{E - 2c_1(r_1 + n^2 r_2)\} = Ec_1 - c_1^2(r_1 + n^2 r_2) - K$

$\therefore K = c_1^2 r_1 + n^2 c_1^2 r_2$

$= c_1^2 r_1 + c_2^2 r_2$

Hence to obtain the maximum efficiency from such a system the energy wasted in the lines and armatures must be equal to the energy spent in exciting the magnets and overcoming the mechanical friction; in other words the variable and fixed losses of energy must be equal.



Electro-medical experiment on Lithium.

Observer Lehmann. 9th Sept: 89

A glass funnel of 7.5 cms diam: at aperture was closed by a piece of sheep bladder a mm thick, thus giving a porous diaphragm of 44.229 cms. This funnel was filled with slightly acidulated water and a platinum wire passing through the tube formed the negative electrode. The whole was then immersed about 1 cm. below the surface of a 2½% solution of Li_2O_3 but above the bottom of the dish about 1.25 cms. A second platinum wire formed the + electrode. A current of 0.15 amperes was then passed through the apparatus for 75 minutes. The funnel was then removed and emptied. The contents were mixed with a solution of Na_2PO_3 and the mixture evaporated to dryness. The residue was then heated with water to dissolve the sodium salt and left for 12 hours. The final precipitate was found to contain 0.5 grammes of Li_2PO_3.

The experiment was repeated under similar conditions without employing the current. After 75 minutes immersion the same treatment repeated gave for diffusion 0.3 grammes of Li_2PO_3 so that it was supposed that the current had been the cause of the action 0.2 grammes being transferred in the first experiment by endosmose. 0.2 gm Li_2PO_3 represent 0.061 of Li_2 and 0.131 of Li_2O.

Batteries.

A phonograph NaHO battery of four cells which had been discharged once was employed to run a cast iron armature. It was kept operating during the day time and taking off a chip continually. It failed to take a chip at speed after 50 hours work. This being an unfavorable result, repeated test.

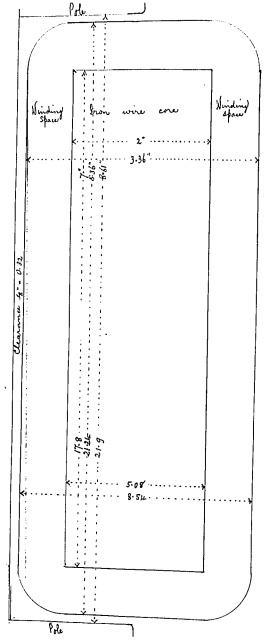
These phonograph cells of the large type are stated by Mr Gladstone to have an average EMF of 0.64 volt and an int: res: of under 0.03 ω (0.025 to 0.03.)

Two phonograph cells (NaHO) of the small type were compared with a Leclanché cell. The phonograph cells had the following dimensions. The glass jar has a height to the neck inside 13 cms 5⅛". Diameter inside 7 cms = 2¾". Diam: of neck inside 4.7 cms = 1⅞", closed with a paraffinide cork. Zinc plate (not) length 16 = 6⅜" diam: 0.9" = 0.6". Copper peroxide plate length 12 cms 4⅞" breadth 1.7 cms = 0.75". Thickness 0.8 = 1/32".

In the first trial, the clock automatically changing the battery every five mins: on 2ω. The NaHO cell failed after 72 hrs, and the Leclanché after 18 hours. In the second trial with the same cells and plates but with the liquid renewed, the NaHO became exhausted after 68 hours (30 actual work) did not even at starting recover. Records on Burns Book. No. 10. of Burns Book.

The model for the small zinc water plate was completed on Saturday afternoon the 14th September. It was taken to Silver Lake and the plate remained caught. The bristles were good hold, but the plate reduced with Zinc only about 1½% as 1/8" = 4/32, became reduced about 1/32nd.

Full size section of armature parallel to axis. also pole piece



Length of lowest armature turn		45.76	18"
" " uppermost	" "	59.56	23.44
" " mean	" "	52.66	20.72

Problem. To so modify the Transformer designed on pages 37 and 39 as to let it supply two motors of the design given on page 47 with 7 HP each at full load.

If the res: of the primary coil of the transformer be 5 ω and " " secondary circuit (joint res:) 0.0175 ω

Then the maximum amount of work will be done when a the secondary circuit current $= \frac{48000}{2(5+2500\times 0.0175)} = 1060$ amp.

Taking the energy lost in the coils by heat @ 50% or in other words the res: of the coil as 50% of the secondary circuit res, the energy required at arc as follows. available for car 7 HP 5250 Watts

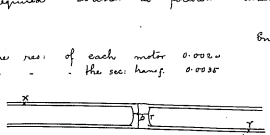
" " magnet 100 "

" " motor friction 250 "

Energy absorbed by car motor 5600 "

The res: of each motor 0.002 ω

" " " the sec: transf. 0.0035



If T be the position of the transformer X and Y be two cars supported at full limit distance of l feet. Then the res: of the secondary ckt =

transformer sec:	0.0035
two motors in ∥	0.0010
two lines in ∥	0.00267
	0.00767

The energy lost at full load in the transf: sec. $= (1060)^2 \times 0.003 = 3370$

" " " " " " " " " line $2(530)^2 \times 0.00767 = 4125$

" " " " " " " " " motor $2(530)^2 \times 0.002$ 1120

Heat waste 8615

Car motor supplies 11400

Transformer secondary absorbs 20000

Fall of potential in transformer secondary 3.18 volts P.D. at terminals 16.82

" " " " line 3.89 " " " motor 12.93

" " " " motor armature 0.53 " " " " 12.43

electrical efficiency of motor $\frac{12.40}{12.93} = 0.96$

commercial efficiency of motor $\frac{5250}{5700} = 0.92$ ∴ $\frac{5250}{6260} = 0.84$

efficiency of system from transf: sec: to motors 0.57

The winding is therefore required of a transformer whose pr: and sec: res: shall be 5 ω and 0.003 ω the generated emf to be not less than 20 volts at full load and to be little above 20 volts when running light. The ampl: of current to be 48

The armature to be divided into 360 equal parts 180 for each circuit and the pr: + sec: winding alternate 90 bars in each circuit, and the pr: + sec: winding alternate 90 bars in the secondary commutator or 1 to each two blocks. 180 bars in the fine wire or primary commutator or one to each block. The ring to be 7" broad on the iron wire and 2" thick. (17.8 + 5.1)

If #13 B.W.G. be employed for the coarse winding in six layers of two turns each. the length of the mean turn being 1.728 feet and the res: 1.2×10^{-3} ω per foot $= 207 \times 10^{-3}$ ω per turn $= \frac{2.07 \times 48}{48}$ $= 0.0014$ ω in all and with connections 0.003 ω the area of the wire is 9025 cmc + 48 carry the current $= \frac{48 \times 9025}{1060} = 410$ cmc per ampere.

The diam: of #13 B.W.G. is 0.095" = 0.110" covered, and the wire with = 0.220" + 3 thickness of paper = 0.232" + the wire of diam 0.042" (#19 B.W.G) = 0.055" covered = 0.452 × 180 = 81.36" circumference = 25.9" say 26" diam: internal + 30" diam: external.

The fine wire coil has a resistance of $\frac{45}{60} \times 48 \times 1.728$ feet of #19 B.W.G = $5.40 \times 1.728 \times 5.852 \times 10^{-3}$ = 5.46 ω say 5.5 ω perhaps 6 ω hot.

#19 wire has an area of 1760 cmc + 60 carry the current = 7056 cmc. and with an efficiency of 90% + 20,000 Watts generated in the secondary ckt the energy absorbed in the primary = 22,200 Watts @ 960 volts = 23.14 amps = 305 cmc per ampere. 23.14 × 6 = 139 volts drop in armature = 1100 volts at machine terminals.

Particulars of Transformer.

Length	31·6"	9·6
Breadth	22·4"	5·2·3
Height	34·5"	8·7·6
Length of core	12"	30·5
Diam.	7·5"	19·1
Space between limbs	3"	7·6
Yoke (inside)	17½"	44·5
(outside)	22·4"	5·2·3
Breadth	7·5	19·1
Thickness	3"	7·6
Clearance	2"	5·1
Length of poles for		62·6
Diam. of magnets for	3·5"	9·0·8
	2·5"	6·4·0
. . windings	(for 31·0) (for 24·0)	79·37 62·5
Breadth of wing	7"	17·8
over core	5·16"	21·0
Thickness of wing	2"	5·1
over core	3·36"	8·5

Magnetic data.

Useful flux 1585000

Leakage allowed 391000

Total calculated for 1976000

$\mathcal{E}$ in core 6790

. armature 21600

Reluctance of winding-space 0·0086

. rest ck 0·0032

Size of wire no magnet # 22 B.W.G. 0·028"

Total weight per core 164·2 lbs.

Total weight magnet wire 134 lbs

Winding space 11" long 1" deep

33 layers of 300 turns per layer.

Amperes in field 0·605

Turns of wire 8000

Ampere turns 5250.

Weight

2 core each 44·2×12 = 530 c.i. = 138 lbs = 552

2 frames each (102·3 − 30·5) × 70 × 3 = 22362 . . . 1,150

1 wing = 70 − 33 = 17·4 sq.in × 7·1323 = 123 c.i. 308

secondary wire 190×2·4×12 = 10,900 ft . 60

primary . 180×12×12·6 = 2,720 . 76

shaft + commutator . 200

Bolts + frames bearing + plumbing 600

3000 lbs total wt. 3412

Commutator

180 bars for primary

30 . . sec ckt

Winding of commutator

180 bars of pri #19 B.W.G. 12 layers of 15 turns in each

180 . . sec . #13 . 6 . . 2 . . in

Res. of primary ckt. 6·0 ohl

. . sec . 0·003

Max. energy in sec. at full load 3370 watts

Current . . . . 1060 amperes

Current in primary . . . 23·1 .

Max. energy . . . . 3200 watts

Drop of pot. at full load in sec 3·18 volts

. . . . pri 139 volts

P.D. at terminals of sec full load 16·8 .

. . . . pri . 1100

Energy delivered to lin. at full load 254410

. . . magnets . . 2700

257110

Delivered loss in friction 2000 watts

. . . . for 3200

. . . . sec 3370

. . . . line 4125

. . . . motor 1120

. . . . magnet 2700

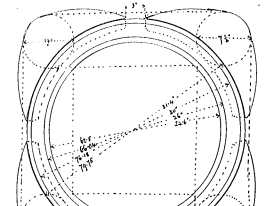
. . . . friction 700

14215

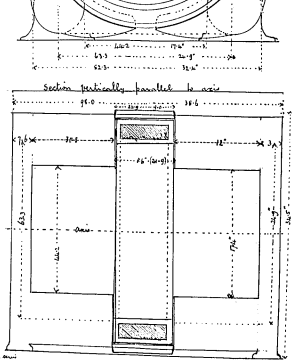
= watts consumed 254710 + 10700 available

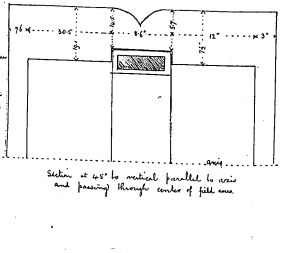
efficiency of 96½ %

Vertical section at right angles to axis.



Section vertically parallel to axis





Section at 45° to vertical parallel to axis and passing through centre of field coils.

Magnetic circuit of Transformer.

The peripheral speed of the armature = 14000 ft per min = 2000 cms per sec and 45 turns in the secondary winding generate 22·5 volts = 0·5 volts (running light) per turn, the effective length of each turn is 29·0 cms and the field necessary is thus $25/2 \cdot 9 \times 10 \times 2 \cdot 0 \times 10^8 = \frac{25 \times 10^8}{5 \cdot 8 \times 10^8} = 862$ amps.

The total length of pole surface is 59 cms and the breadth 31·0. The total length of one quadrant of armature is 62·6 and the breadth 29 cms = 1816 sq. cms = 1,565,000 lines employed. Allowing 25% of this for leakage 391,000 + 1,565,000 = 1,956,000 lines have to be generated. The cores are about 141 cms. and their half mean is 143 sq. cms. $\frac{l}{a} = \frac{141}{143} = 0 \cdot 2761$ for = 1260 p. 500 to 0·0086

Two of these $\frac{l}{a}$ cores are in series + a similar pair in parallel in each circuit so that the reluctance is that of one core 0·0007736

The yoke ckt is about 63 cms long and 145 cms $\frac{l}{a} = \frac{63}{182} = 0 \cdot 4345$

$\mathcal{E} = \frac{1956000}{145} = 6750$ $\mathcal{E} = 500$ $\mu = 0 \cdot 0008690$ lns in ‖ = 0·0004345

The pole is about 12 cms long and 2640 in area $\frac{l}{a} = \frac{12}{2640} = 0 \cdot 05$

then an lns in series = 0·1 ÷ μ 1000 = 0·00010

The air space is ⅓ (0·32) long and area 1900 sq. cms $\frac{l}{a} = \frac{0 \cdot 32}{1900}$ = 0·000356

The armature length is about 20 cms

its area is 0·8 × 5·08 × 17·8 = 72·6 sq. cms. $\mathcal{E} = \frac{1565000}{72 \cdot 6} = 21600$. p. 500

$\frac{l}{a} = \frac{20}{72 \cdot 6} = 0 \cdot 278$ the average value of μ is probably 200 . 0·001390

0·003291

The winding space has a length of 1·75 and a breadth of 1900 sq. cms $= \frac{l}{a} = \frac{1 \cdot 75}{1900} = 0 \cdot 000972 \times 2$ 0·003888

0·007500

To generate 2000,000 lines the exciting power must be 1260 with this reluctance. = 7000 on each core = 5870 ampere turns on each core. To make more certain let us take 6000 ampere turns per core.

Although it is cheaper to some extent to supply the field from the secondary core, yet the tendency to reduce the ampere turns when load comes on the transformer makes it in this case more desirable to supply the field from the primary terminals. The surface of each core is 1800 sq. cms. and allowing 50 sq. cms per Watt gives 36 Watts for each core, as a trial value. With 8 in series there will be 1100 ÷ 8 = 137·5 volts on each. 36/137·5 = 0·262 amperes = 525 ω res. and the total depth being 0·5" = 1·27 cms, the winding space is 11 × 2·54 (317 − 236·5) = 27·94 × 80·5 = 2250 sq. cms

$$d = -0 \cdot 02 + \sqrt{\{0 \cdot 0004 + 0 \cdot 00153 \sqrt{\tfrac{2250}{525}}\}}$$
$$+ \sqrt{\{0 \cdot 0004 + 0 \cdot 00153 \times 2 \cdot 071\}}$$
$$+ \sqrt{(0 \cdot 00317 + 0 \cdot 0004)}$$
$$+ \sqrt{(0 \cdot 00357)}$$
$$+ 0 \cdot 0598 \text{ cms} - 0 \cdot 02$$
$$+ 0 \cdot 04 \text{ cms} = 0 \cdot 016'' = \# 27 \text{ B.W.G.} = 0 \cdot 028'' \text{ cond.}$$

= 0·0492 lbs. per ω = 10·1 lbs. on each core = 84 lbs. in all.

allowing 30 watts to the surface = 40 Watts = $\frac{40}{137 \cdot 5}$ = 0·2909 amp = 13750 turns. With ½" coiling depth = 5·5" coiling area = 5,500,000 cmb ÷ 127·5 = 43,100 cmb = 0·020 × 0·028" copper. To give 0·2909 amp requires $\frac{137 \cdot 5}{0 \cdot 437}$ = 315 ω

$$d = -0 \cdot 02 + \sqrt{\{0 \cdot 00004 + 0 \cdot 00153 \sqrt{\tfrac{2250}{315}}\}}$$
$$+ \sqrt{\{0 \cdot 0004 + 0 \cdot 00153 \times 2 \cdot 673\}}$$
$$+ \sqrt{(0 \cdot 0004 + 0 \cdot 00409)}$$
$$+ \sqrt{0 \cdot 00449}$$
$$-0 \cdot 02 + 0 \cdot 067$$
$$+ 0 \cdot 047 \text{ cms} = 0 \cdot 0185'' = \# 26 \text{ B.W.G.}$$

= 0·83 lbs per ω = 9·45 lbs per core = 75·8 lbs in all.

round the mean turn = 15·13" = 1·26 feet. 31·39 ft per ω @ 315 ω = 9900 ft

= 7850 turns = 31·20 a.T.

allowing 20 sq. cms per Watt gives 0·021" with ½" depth = # 26 B.W.G. 0·022" = 9650 ft per ω = 300 turns per layer

= 33 layers = 1" = 114·24 lbs per core = 134 lbs in all

Taking (2) as correct.

$R = 0.00734$

$c = \frac{1}{10}$

$\frac{Rc}{2} = 36.7 \times 10^{-5}$

$p = 6.0 \times 10^{-5}$ allowing 10% on 10 miles.

$\frac{Rc}{2p} = 6400$

$\frac{Rc}{2p}(t+T) = 6400 \times 250 = 1,600,000$

$\sqrt{6400 \times 250} = 1600$

$\frac{\sqrt{6400 \times 250}}{2} = 620$ ft

∴ the economical distance is 620 feet.

A transformer weighs 3000 lbs if above designs on page 52–53 be accepted, and @ $0.033 lb will cost $1000.

t depreciation annually $100

T interest and superintendence, oil, bushes etc $150

$t + T = 250$

The specific resistivity of iron being 9600 ohm. w. @ 0°C

1 foot of bush 1 sq. in. in section has a resistance of 52 microhms

conductance of 19,230 mhos

1 c.mil foot of copper has a resistance at ordinary temp of 10 ω

conductance " " " of 0.1 mho.

1 " " " " " weight " " 3.018×10^{-4} lbs.

Problem: To Determine the most economical distance between the Transformers, on a double car track

Let t be the depreciation of a transformer yearly in $.

r - - annual interest at current rate not only on the first cost of the transformer but also on the cost of its installation and necessary connection expenses together with the cost of keeping it in order, oil, + bushes $.

D - - distance from one end of the road to the other.

N - - number of car trips per annum (to the end of the track and back)

w - - energy integral, expended in driving a car at full load to the limit or from the limit to the transformer (watts)

c - - conductance of one cir. mil. foot in mhos

k - - " " " foot of iron track . . .

p - - annual price of one cir. mil foot copper in int. + dep. $.

n - - number of cir. mil of copper conductor laid down.

ε - - cost of a watt in the secondary circuit $.

R - - limiting resistance of the track.

x - - distance between the transformers.

It is assumed that each transformer is so loaded during working hours as to supply the full amount of $2w$ watts to each car as it comes over the left hand limit and runs over to the right hand limit. With varying load this is not true, but w may be estimated at a fair average allowance by examination of existing data.

Then the number of transformers is $\frac{D}{x}$

Their total cost per annum is $\frac{D}{x}(t+T)$

The number of discharges of energy in one trip (there + back) $\frac{4D}{x}$

" energy expended on each $\frac{4Dw}{x}$

" expense incurred in supplying this energy $\frac{4Dw\varepsilon}{x}$

" annual " " " " " $\frac{4ND w\varepsilon}{x}$

" " expense incurred on the account of conductor investment is $4Dnp$

Total variable annual expense $E = \frac{4DNw\varepsilon}{x} + \frac{D(t+T)}{x} + 4Dnp$

but $R = 2x/(nc+k)$ ∴ $nc + k = \frac{2x}{R}$ $n = \frac{2x}{cR} - \frac{k}{c}$

$$\therefore E = \frac{4DNw\varepsilon}{x} + \frac{D(t+T)}{x} + \frac{8Dpx}{cR} - \frac{4Dpk}{c}$$

$$\frac{dE}{dx} = -\left\{4DNw\varepsilon \times \frac{1}{x^2} + \frac{D(t+T)}{x^2}\right\} + \frac{8Dp}{cR}$$

for a minimum $\frac{dE}{dx} = 0$ $\frac{8px^2}{cR} = 4Nw\varepsilon + (t+T)$

$$x^2 = \frac{Rc}{8p}\{4Nw\varepsilon + (t+T)\}$$

$$x = \frac{1}{2}\sqrt{\frac{Rc}{2p}\{4Nw\varepsilon + (t+T)\}} \qquad (1)$$

Rc = Number of cir. mil feet in the limiting track

$\frac{Rc}{2p}$ = Number of cir. mil feet in the limiting distance per $ of annual conductor charge

$4Nw\varepsilon$ = cost in $ of the energy wasted annually in the conductors by our transformers

$t+T$ = cost annually of one conductor.

If it is assumed that $w = ax$ i.e. varies directly with the time on one section

Then $E = 4DNax + \frac{D(t+T)}{x} + \frac{8Dpx}{cR} - \frac{4Dpk}{c}$

$$\frac{dE}{dx} = -\frac{D(t+T)}{x^2} + \frac{8Dp}{cR} \quad \therefore \frac{8Dpx^2}{cR} = D(t+T) \text{ for a minimum}$$

$$\therefore x^2 = \frac{cR}{8p}(t+T)$$

$$x = \frac{1}{2}\sqrt{\frac{cR}{2p}(t+T)} \qquad (2)$$

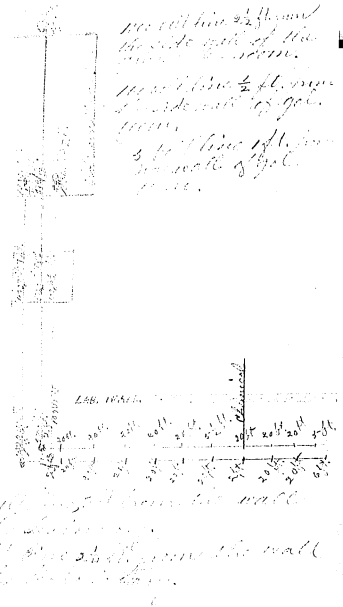
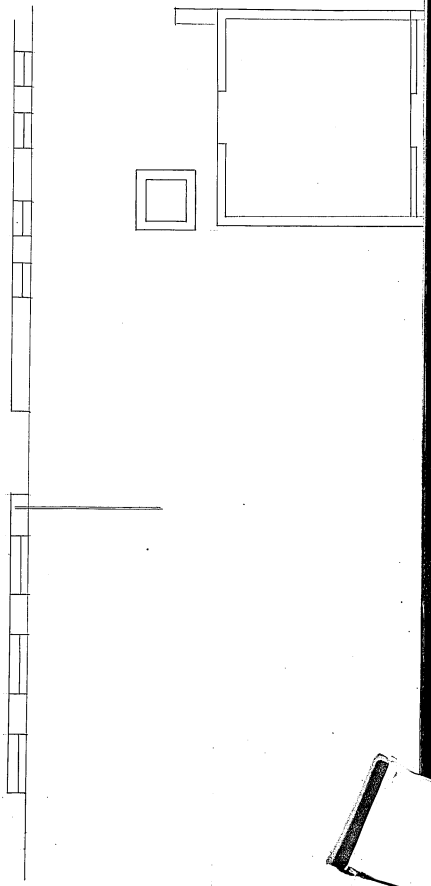
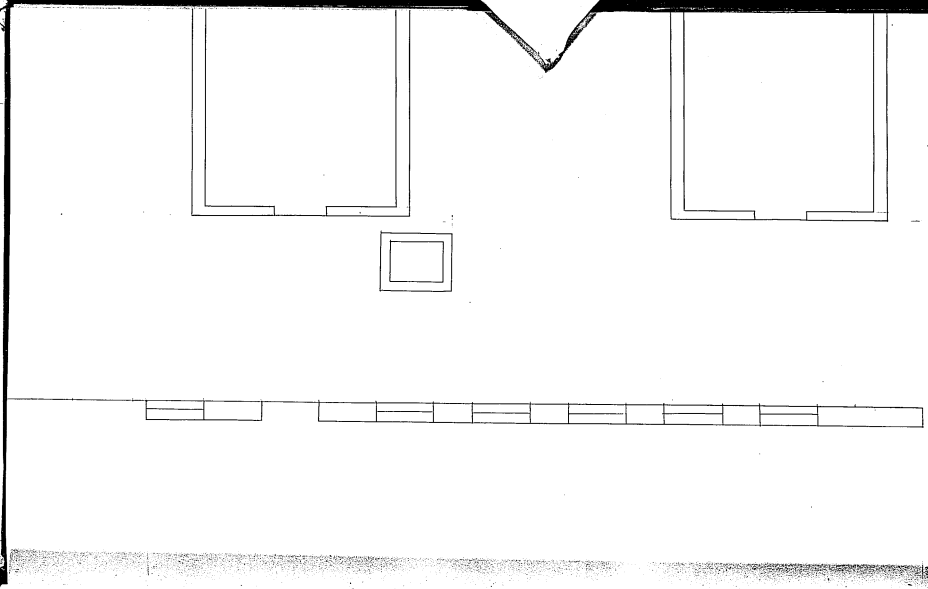


Diagram shewing the arrangement of pipes + tubes in the laboratory.





Phonograph Battery Tests

To compare the relative behavior of cast iron and wrought iron armatures have a cast-iron motor with a 4 cell NaHO battery that had already run one term. It was kept taking off a chip almost the entire period. It failed to take the chip after 50 hours. The battery was cleaned up and refreshed. It was then set to work on a wrought iron motor under similar conditions. It failed after 47½ hours. Another test was made between these two machines with two bichromate cells, regular phonograph chromic acid type. Two cells in series were used. The wrought iron motor ran for 8 hrs and 50 mins. The cast iron 8 hrs and 30 mins. A third test was made in the galvanometer room. Two machines like those above mentioned were used. One cast iron the other wrought iron. Two phonograph 4 cell NaHO batteries were made up one for each, and the motors were driven light. They started at 10:20 o'clock 16th Sept. and stopped at 21 o'clock on the 19th in the case of the cast iron and 6 o'clock on the 21st in the case of the wrought iron armature runs of 76 + 100 hours respectively. The batteries were then recharged and the zincs amalgamated, and the armatures exchanged. The cast iron machine stopped after 27 hours continuous run the resistance being 0.85Ω. The wrought iron machine stopped after a continuous run of 85 hours. Another motor of wrought iron was set running by a battery whose plates had been cut down to half width. It ran continuously for 66 hours, when the int: res: became very high.

Some experiments were next made with 6 cells delivering 4 – 6 amperes of current to represent the behavior of such batteries in connection with a Phelps motor. The ext: res: was 0.5Ω. The current commenced at 2.5 amperes rising after 3 hours to 5.2 (rising subsequently) to 5.7 until after 46 hours when one cell showed a high res: + some chemical decomposition stopped the output of the set. The fluid was milky + smelt of gasolene. The same test was repeated with the same cells but the (milky) amalgamated zinc plates. The current commenced at 5 amperes and continued practically for 60 hours. The int: res: per cell was 0.07Ω (average) and the average E.M.F. 0.67 volt.

Table showing trials of cast iron armatures in running phonographs

No.	Battery	Material of armature	Date & Time of Start		Date & Time of failure		Lifetime	Condition of run.	Speed	Remarks
1	4 cell NaHO	cast iron	16.00	16.IX.89	21.	19.IX.89	75	light	120	
2	. . .	wrought	21.00	16.IX.89	6	21.IX.89	100	"	"	
3	. . .	wrought					85	-	-	Batteries refreshed
4	. . .	cast					27	-	-	
5	. . .	cast malleable	15	15.X.89	4.	19.X.89	88	-	-	
6	. . .	"	15	15.X.89	1.	19.X.89	85	-	-	Gas
7	. . .	cast malleable, half width	8	2.XI.89	2½.	6.XI.89	90	-	-	

Experiments and Data on the
Grounding of the Neutral in 3 wire systems and the
use of the ground in place of the neutral main

September 25th Wednesday.

Employed a ground at the phonograph factory using the hydrant as connection with some 50 feet of #8 copper wire. Made a similar ground at the laboratory by a bolt on the bedplate of the #1 engine.

Res: of mains measured as follows.

+	0.05ω
0	0.07ω
−	0.05ω
	0.07ω

One joining up grounds, and neutral etc. which appeared to make the res: of the ground nil. Joined up both ground and neutral at the phon: factory and used each alternatively at the laboratory. Set the factory motor on one side, making a load of 170 amperes on one side and 90 amperes on the other. Using the ground circuit only as the neutral, the effect of joining up the neutral main in multiple with it only made a change of one volt at the laboratory terminals. Experimentally found that a lead wire was just fused on the neutral main side, which took 2·3 × 2 ÷ 41·95 = 33·8 amperes so that of the 90 amperes travelling along the neutral circuit about 34 close a path of 0·07ω, the difference 46 going via the ground. The effective res: of the ground circuit was thus 0·05ω, or less than the neutral proper.

Inductance Measurements

Two phonoplex induction coil 1·5 cms clearance parallel to each other + on wooden base. Axes 5 cms apart. Length over all 10·5 interflange 9·5. Int: diam: 3·5 Ext: diam: 1·55. Core 1·2 of wire

Coils	Bridge Ratio	Res: of coil	Condenser	KBD	Inductance Quadrant	Inductance Kilometer	Sum Kilometer	Discrepancy	
A	10000/100	6.975	1·414	9.863	0·0986	986	2017		
B	23.5°C	6.992	1·475	10·31	0·1031	1031			
(A) (B)		3·544	1·210	4·299	0·0429	429		195	
A+B.		13·856	1·596	22·12	0·2212	2212			

Testing the effect of mutual inductance at so short a distance repeated test after removing one coil from the base to about 25 cms

Coils	Bridge Ratio	Res: of coil	Condenser	KBD	Inductance Quadrant	Inductance Kilometer	Sum		Joint Ind.	Dis.
A	10000/100	6·892	1·405	9.684	0·0969	968	1986			
B	21.6°C	6·927	1·469	10·180	0·1018	1018				
(A) (B)		3·492	1·344	4·694	0·0469	469		12	496	27
A+B		13·745	1·436	19·740	0·1974	1974				

The phonoplex coil has therefore practically zero res: + 0·1 quadrant

Experiments and data connected with the use of the ground in place of a neutral wire.

On the 26th September, all the system was operated during the evening without a neutral wire. In ~~the~~ each house the center of the installation was connected with the waterpipe system, and the neutral plug removed. Similarly the factory grounded on the hydrant mentioned on the preceding page. The result was quite successful. On removing the neutral connection at the laboratory and grounding the dynamo connection on the bedplate of the engine, no change in adjustment could be observed. The balance was successfully maintained in the houses but owing to the voltmeter being a shorter connection than usual, the voltage in the park was a trifle too low. In Mr. Edison's coachhouse + Mr. Burkis coachhouse, a ground had been omitted and the result proved disastrous to some of the lamps in those buildings. That however was no fault of the principle involved.

Azimuth and Local Time Observations

September 29th Sunday.

Apparent altitude of sun's center 32°.
Time of Observation 14. 49. 40 by watch.
Position of Instrument vertical axis 63" (160 cms) south of end of Equatorial platform midway between rails

Observed magnetic declination 8° W.
With axis of telescope brought to meridian the reading was N 109°. 26'. 0 B 70°. 26'. 00
assume - - - to bisect the center of the pagoda roof of a house near a telegraph pole in a line nearly at right angles to the roof of factory)

A	109°. 28'. 30 B 120°. 26'. 00
	109°. 57'. 30 109°. 57'. 00
Mean	109°. 27'. 37'. 5 109°

Azimuth of pagoda center E

How angle observed 47°. 19'. 20" = 3. 9. 17 (L. M. S.)
Equation of time for noon 9M. 9.48 (M. E.)
Difference for next 24 hrs - 19.4
8 hrs - .6.5
9.55

	9.55
Local Mean time	14. 59. 22
	1. 00
N.Y. Mean time	15. 00. 22
Watch	14. 49. 40
Error –	10. 42

Second measurement.
Apparent altitude of sun's center 29°. 30'
M. Time of Obs. 15. 11. 50. by Watch.
Observed magnetic declination 8° W.
With axis of telescope brought to meridian the reading = A 109°. 30'. 00 B 70°. 29'. 00
assume - - - center of pagoda roof

A	109°. 28'. 30 B 120°. 30'. 00
	50°. 1'. 30 50°. 1'. 00
Mean	50°. 1'. 15" Mag.

How angle observed 52°. 49'. 50" 3. 31. 19

Equation of time	9.55
Local M. Time	15. 21. 24
	1. 00
N.Y. M. Time	15. 22. 24
Watch	11. 00
Error –	10. 24

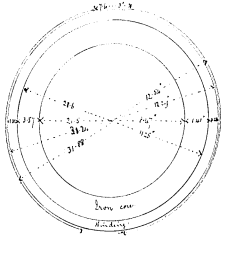
49. 57 375
180. 2. 30
130. 0. 65
But result to det. 50°. 0'. 2"

Clock found to be 1m 23s ahead of watch = 9m. 11s slow

Mathematical Theory of these permeability measurements.

Let l_1 be the length of the standard specimen
- a_1 - - area
- l_2 - - length - - tested
- a_2 - - area - - -

We assume that $l_1 = l_2$ and $a_1 = a_2$ to simplify practice
- L - - length - - large magnet coil
- A - - area - - -
- ρ_1 - - reluctancy - - standard specimen
- ρ_2 - - - - - - - tested
- ρ - - - - - - - large magnet
- ϕ_1 - - flux in l_1 which passes through the circuit on applying the coil L &c
- ϕ_2 - - flux simultaneously in l_2 &c
- ϕ - - permanent flux of magnetic stress in the circuit due to the magnet
- χ_1 - - flux in the air produced by the coil &c
- χ_2 - - - - - - -



Particulars of motor

Peripheral speed	1500 in/per min	3000 ft per min
E.M.F. at terminals when running light	200 volts	

Diameter of ring armature

Int.	21.5	8.47"
Ext.	28.6	11.25"
Thickness	3.97	1.41"
Breadth	17.8	7"
Ext. Depth winding	1.32	0.52"
Clearance	0.32	0.125"

Size of wire on armature 10 B.W.G. 0.134"
Cmils: 18,000

Current at full load 30 amperes each side
C mil per ampere 600 at full load.

Number of layers on armature 3

Turns per block	5 x 3 = 15
Total no. of armature turns	660
Blocks in Commutator	44
Area of armature slot	0.164
Average field	21.33 Gauss
Total calculated flux	2,075,000
Leakage allowed 30%	622,500
Useful flux	1,453,000
Fall of pot. in arm. full load	10 volts
Waste of energy . . .	600 Watts
. field . .	200 .
Total waste at full load	800 .

Field dimensions remain same as those determined for the motor on p. 47.
The field winding is however altered to
15.4 lbs of # 21 B.W.G. wire 0.032" on each limb = 68 lbs in all.
about 20 layers of 150 turns each
Total # turns per limb 3000
. ampere turns per limb 6000
Pot. drop per limb 20 volts per Volt.
Weight of iron on armature 58 lbs p 10 B.W.G.

Problem. To determine the best winding and dimensions for a Bar Motor of 5 kilowatts power at full load, using either an overhead line or subterranean conductor in a conduit.

The motor to be of the Fuller Gramme type, and of about the dimensions shown on page 47. The speed 3000 ft per min = 1500 turns.

The lines to be supplied from the bus-bars of an Solsum Illuminating station of the 3 wire system i.e. at 250 volts pressure. Let us assume at present that this will represent an average pressure of 200 volts at the motors or a general drop in the lines all over the system of 20%.

Then running light the motor must generate an emf. of say 190 volts. The breadth of the armature = 18 cms so that the area generated per sec: = 18 x 1500 = 27000 sq. cms per sec.

At full load let the generated emf be 100 volts then taking the efficiency of the motor @ 85% the power to be absorbed = 5880 and the current will be 59 amperes. Let us try 600 cmils per ampere = 35400 cmils = 0.188" for one wire or 17,000 cmils = 0.134" # 10 wire for two. = 0.134" diam. bars or 0.158" covered. Allowing 0.160" for winding purposes = 0.406 cms and the peripheral of the armature to be 28.6 + 0.4 = 29 cms x π = 91.1 cms ÷ 0.406 = 224 turns say 220. = 44 blocks @ 5 turns each. For half the ring the number of turns = 110 so that the total area swept out per sec: = 2970000 sq. cms ∴ $nf = \frac{190 \times 10^8}{2.97 \times 10^6} = 64 \times 10^2$ with 3 layers (n = 3)

$f = \frac{190 \times 10^8}{3 \cdot 97 \times 10^6} = 2133 = 21.33$ Gauss. The thickness of this winding will be 0.514" x 3 = 0.462" + 0.05" for insulation = 0.512" say 0.52" over all. = 1.32 cms Above this the clearance is ¼ = 0.32 cms making the entire 0.645" = 1.64 cms.

Employing the same dimensions for the field magnet the reluctance of the air space is increased from 0.0027415 to 0.0036624 an increase of 0.000884 bringing the total reluctance up to 0.006988 and the same no. of ampere turns will produce ~~26~~ $\frac{2.275 \times 10^4 \times 5.104}{6.988}$ = 2.075 x 10^4 lines of which if 30% are lost = 0.6225 x 10^4 leaves 1.453 x 10^4 lines for use ÷ 7.16 = 20.3 Gauss.

The res. of the armature will be 4g per turn x $\frac{660}{16}$ = 8090 cms = 265.3 ft equivalent of # 10 wire = 0.159 ohm and the fall of potential through this at full load = 10 volt = 600 Watts.

When delivering	5 Kilowatts =	5000
waste in friction		2000
. armature & field		800
		7800

drop in arm: 10 volts = 190 = 40 amperes current.

With 10 watts per sq. cm, the current may be 2.0 amperes @ 250 volts with all four coils in series the res. must therefore be 200 w. for lamp = 50 w each bobbin. The diam: of the wire is thus

$$-0.02 + \sqrt{0.00014 + 0.00153 \times \sqrt{\frac{2300}{50}}} \times 478$$

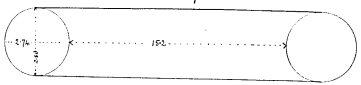
$$0.00014 + 0.01037$$

$$\sqrt{(0.01077)}$$

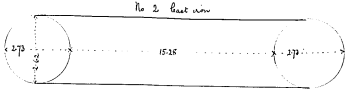
0.104 − 0.02 = 0.0824 cms = 0.033"
= # 21 wire 0.032"
= 15.37 lbs per cm = 61 lbs in all.
= 5000 feet . . = 22,000 ft . .

Mean turn 1.5 ft = 3300 turns = turn 0.05" wide . 150 turns per layer . 22 layers = 1.1"

No 1. Norway iron



No 2 Cast iron



Electro medical Experiment

Having succeeded in forcing lithium by electrical osmose through a bladder, tried the experiment on a man — James Duncan. He kept his hands inserted up to the wrists in a solution of LiCl and NaCl respectively for two hours daily. The current passing through him was 0.004 ampère being as much as he could conveniently stand. At the end of one week after 11 hours total application, tests were applied to his urine collected during that time. By spectrum analysis a solution containing 1 part in 40,000 of LiCl could be detected by a faint red band. No such band was distinguishable from his urine itself, but a condensation of all his urine for the week reduced to the form of sec chloride gave distinct band. The quantity of lithium chloride obtained was 0.22 grammes and this from about 7/8th of the whole week's urine = 0.55 g. from the whole. about 0.09 g. of metallic lithium equivalent to a removal of 2.43 g. urine urea @ 4 per cent.

$$LiCl + C_6H_2H_4N_4O_3 = HCl + C_7H_7LiN_4O_3 — ?$$

Permeability Measurements

Took a welded ring of Norway iron of dimensions shown. The mean diameter = 17.94 and circumference 56.36. The cross section was slightly elliptical, and its area 6.02 sq cms. Overlaid this with one ribbon of rubber tape to a diameter of 2.84 and 2.90 cms respectively. Three layers of #18 B.S. wire 0.0395 (0.100 cm) diam. amount to 0.054" (0.137") with connection wires soldered others were layed on this ring for an angle of 270° ($\frac{3\pi}{2}$). On the first layer were 210 turns on the second 220 and on the outside 212, making 642 in all. Thin rubber paper 0.012" (0.03) was wrapped in a strip round and round between each layer of wire to give a fair surface and a layer of black tape was then added over all. The outside diameter of cross section was then about 4.2.

Took a similar ring of cast iron cast at the phonograph factory of dimensions shown. The mean diameter = 18.01 and circumference 56.5 cms. The cross sectional area was rather more elliptical and it area 2.73 × 2.62 × 0.7854 = 5.62 sq cms. Overlaid with one ribbon of rubber tape and wound with three layers of wound wire just as in the case of no 1. The number of turns in these layers was 212, 212, and 219 making 643 in all. It was wrapped over with black tape so that the two rings resembled each other very closely.

The inductances of the ~~[illegible]~~ cast iron ring was found to be sufficient

No.	Ratio of Bridge	Res. ohms	Permittance	Quadrants	Kilometers	Res. added to coil	Max. Final steady current amperes	Time Const.	H	$\frac{M}{L}$
1	1000/1000	1001.4	0.056	0.0561	560.8	1000	0.00325		0.620	
2		902.17	0.068	0.0611	613.6	900	0.00865		1.231	
3	T.B. 25°C	802.32	0.079	0.0634	633.8	800	0.00705		1.346	
4	Temp of coil 20.5°C	702.32	0.089	0.0625	625.0	700	0.00755		1.499	
5		602.40	0.104	0.0627	626.6	600	0.00560		1.680	
6		502.35	0.127	0.0638	638.0	500	0.01035		1.976	
7		401.35	0.152	0.0615	618.1	400	0.01175		2.243	
8		301.40	0.270	0.0814 ?	813.8 ?	200	0.015640		2.940	
9		201.43	0.319	0.0643	642.7	200	0.02025		3.866	
10		101.50	0.639	0.0649	648.5	100 *	0.03035	0.00065	5.79	
11		91.51	0.704	0.0644	644.2	90				
12		502.35	0.124	0.0622	623.0	500	0.01035			
13		1001.3	0.056	0.0561	560.8	1000	0.00325			

* This critical measurement at which the instrument began to be excessive at 2.11 × 2.2 or 4.29 changes or discharges per sec = 0.23 ÷ 0.00065 = 400 times the time constant.

Meteorological record.

Date 1881	Time	Barometer readings Inches	Corr.	Temp. Corr. to 0° C	Thermometers Max.	Min.	Dry	Wet	Range of temp.	Rainfall 24 hrs	Wind	Weather - Remarks
October	Noon											
1		30.032	76.38	74°	29.906	72°	51°	64°	42°	0.15	NW	Raining
2		30.084	76.43	76°	29.932	74°	46°	63°	60°	—	NW	Fair
3		30.062	76.34	73°	29.939	70°	39°	60°	59°	—	NW	Fine
4		29.912	75.98	64°	29.816	70°	43°	65°	62°	—	NW	Fair
5	"	29.892	75.82	64°	29.676	72°	42°	64°	60°	—	NW	Fine
6		29.760	75.69	61°	29.678	69°	46°	56°	50°	0.19	NW	Overcast
7		29.916	75.99	68°	29.808	67°	36°	63°	60°	—	N	Fine
8		29.836	75.78	74°	29.710	62°	30°	57°	49°	—	N	Overcast
9		29.842	75.82	72°	29.722	60°	38°	49°	42°	—	NE	
10		29.966	76.11	76°	29.854	56°	36°	43°	38°	0.01	NE	Fair
11		29.998	76.17	70°	29.836	57°	39°	50°	46°	0.03	NE	Fair
12		29.934	76.04	73°	29.813	52°	33°	48°	45°	—	NE	Overcast
13	"	29.724	75.50	79°	29.598	47°	38°	48°	42°	0.28	W	Rain "
14		29.628	75.26	75°	29.609	43°	36°	43°	42°	0.38	W	Overcast
15		29.796	75.63	79°	29.617	50°	40°	53°	45°	0.50	W	Fair
16		30.028	76.27	77°	29.843	57°	42°	52°	43°	—	NE	Fine
17		30.000	76.19	76°	29.871	54°	38°	54°	49°	—	NE	Fine
18		29.970	76.12	79°	29.829	58°	48°	54°	47°	—	W	Fine
19		29.934	76.04	71°	29.810	55°	36°	47°	40°	—	W	Fair
20	"	29.850	75.80	75°	29.721	63°	38°	61°	58°	—	W	Fine
21		30.022	76.26	73°	29.828	66°	43°	46°	43°	0.06	W	Overcast
22		30.200	76.71	76°	30.058	49°	40°	48°	42°	—	W	Fine
23		29.964	76.1	79°	29.858	54°	31°	46°	41°	—	NE	Overcast
24		30.124	76.82	85°	30.087	50°	31°	42°	39°	—	E	Fine
25		29.926	75.94	60°	29.760	52°	35°	43°	39°	—	NW	Fair
26		29.936	76.04	60°	29.852	55°	38°	53°	51°	—	NE	Fair
27		29.712	75.40	62°	29.622	54°	36°	52°	50°	0.60	NE	Rain
28		29.600	75.17	75°	29.471	61°	51°	56°	53°	0.32	N	Raining
29		29.916	76.05	72°	29.836	59°	43°	49°	46°	—	W	Fair
30		30.012	76.22	73°	29.884	58°	49°	53°	49°	—	N	Misty, overcast
31		30.054	76.33	70°	29.940	62°	48°	57°	52°	—	NW	Overcast
Nov.	1	30.050	76.32	72°	29.930	56°	45°	56°	54°	0.08	W	Fair
2		29.960	76.10	69°	29.864	56°	43°	54°	50°	—	W	Fair
3		30.064	76.34	72°	29.944	54°	31°	50°	44°	—	NE	"
4		30.064	76.37	60°	29.999	59°	38°	53°	52°	0.17	NE	Overcast
5		30.002	76.19	50°	30.098					—	W	Fair
6		30.122	76.50	46°	30.092					—	W	Fine
7		30.096	76.40	46°	30.097					—	W	"
8		30.010	76.23	51°	29.973	54°	33°	54°	53°	—	W	Overcast
9		29.824	75.74	77°	29.697	52°	42°	50°	49°	1.2	W	Rainy
10		29.820	75.77	76°	29.678	54°	50°	51°	50°	0.06	NE	"
11		29.920	76.00	75°	29.791	56°	38°	53°	50°	0.05	NE	Overcast
12		30.100	76.46	82°	29.950	54°	40°	52°	50°	0.04	E	Fine
13		29.716	75.48	80°	29.572	56°	45°	52°	51°	0.07	NE	Overcast
14		29.750	75.56	82°	29.600	58°	51°	58°	55°	0.80	SW	Fine
15		30.110	76.52	74°	29.989	48°	29°	39°	38°	—	W	Fine
16		30.462	77.37	70°	30.348	60°	26°	34°	32°	—	W	Fine
17		30.208	76.73	63°	30.118	36°	24°	36°	34°	—	NW	Fine
18		30.050	76.33	70°	29.936	45°	33°	40°	39°	—	NE	Overcast
19		29.614	75.22	70°	29.500	49°	39°	46°	46°	1.00	NE	Rainy
20		29.576	75.14	70°	29.469	53°	33°	48°	46°	0.55	W	Overcast
21		29.608	75.22	81°	29.461	49°	39°	48°	47°	—	SW	Fine
22		29.324	74.50	79°	29.181	51°	46°	50°	47°	—	SW	Fair
23		29.750	75.55	80°	29.606	51°	45°	50°	47°	—	NSW	Fair
24		30.010	76.28	58°	29.951	51°	40°	51°	49°	0.39	W	Fair
25		30.066	76.37	75°	29.947	51°	36°	47°	46°	0.20	W	Rainy
26		30.432	77.30	70°	30.318	54°	36°	50°	50°	0.60	W	Fine
27		29.996	76.02	72°	29.926	52°	39°	51°	51°	0.70	NW	Rainy
28		29.650	75.31	76°	29.500	50°	35°	50°	48°	1.28	NW	Dull
29		29.700	75.45	69°	29.589	46°	25°	42°	39°	—	W	Fine
30		30.150	76.57	60°	30.057	40°	25°	33°	32°	—	W	Snow during night
Dec.	1	30.080	76.40	60	29.99 6	38	33	38	36	—	NW	Fine
2		30.000	76.19	67°	29.995	43°	30°	42°	39°	—	W	Fine
3		29.864	75.90	60°	29.780	45°	20°	36°	32°	—	W	Overcast
4		30.306	76.97	65°	30.207	43°	12°	30°	19°	—	W	Snow
5		30.000	76.19	64°	29.944	43°	13°	34°	33°	—	NE	Overcast
6		29.904	75.94	75°	29.771	42°	32°	41°	39°	0.01	E	Fine
7		29.950	76.07	70°	29.836	42°	30°	41°	38°	—	SW	Fine
8		29.966	76.17	75°	29.88	46°	35°	40°	38°	—	SW	Overcast
9		29.988	76.18	72°	29.864	61°	38°	50°	50°	0.55	SW	Rain
10		30.240	76.82	77°	30.133	60°	32°	44°	42°	—	W	Fair
11		29.746	75.60	77°	29.591	52°	40°	45°	43°	—	W	Fine
12		30.070	76.30	75°	29.836	50°	38°	50°	48°	0.26	W	Overcast
13		29.784	76.67	75°	29.632	54°	38°	50°	48°	—	W	Overcast

Permeabilities continued from page 61.

The corresponding measurements with the wrought iron ring were as follow :-

Bridge Ratio	Rec. dev.	Permittance	Quadrants	Kilometers	Rec. added to cent	Final steady recy. current amperes	Lenz Const.	H in the ring.
1000/1000	1001.4	0.031	0.03105	3115	10000	0.00325		0.620
1000/900	902.20	0.040	0.03610	3610	900	0.00645		1.231
	802.30	0.045	0.0361	361.0	800	0.00705		1.346
	702.35	0.050	0.0351	351.2	700	0.00785		1.499
	602.45	0.063	0.0380	379.6	600	0.00880		1.680
	502.50	0.080	0.0420	420.	500	0.01035		1.976
	401.47	0.120	0.0482	481.8	400	0.01175	0.00012	2.243
		unreliable beyond		from	unbearable	of spot.		

The number of turns being 642 spaced over 3/4 lbs of the ring) whose mean circumference = 42.27 cms gives $642 \times 1.75^{\circ} \div 42.27 \times 4\pi = 190.9$ c. in H.

On the dimensions of the sun on the assumption that its density is equal to that of the earth

Commencing with the outermost planet of our system the densities are stated as follows:-

	new Encyc.	
♆	0.935	
♅	0.99	
♄	0.66	
♃	1.21	
♂	5.06	
♁	5.5	
♀	5.06	5.65 by Lockie's Atlas 1887
☿	6.52	6.16 " " " "
☉	1.375	

From this list it is evident that with the exception of Saturn, itself a planet of exceptional form (the density of the moulton increases toward the center. The sun however is a very) notable exception. We have to allow for the sun's heat in estimating his dimensions but assuming that he has a solid nucleus of density equal to that of the earth and that the rest of his bulk is of gaseous raw material then the true dimensions of his solid or liquid nucleus would be determined as follows:-

Let R be the sun apparent radius

r - - - nucleus -

$$\frac{4}{3}\pi R^3 \times 1.375 = \frac{4}{3}\pi r^3 \times 5.5 + \frac{4}{3}\pi (R^3 - r^3) d$$

$$1.375 R^3 = 5.5 r^3 + (R^3 - r^3) d$$

$$r^3 (5.5 - d) = R^3 (1.375 - d).$$

$$r = R \sqrt[3]{\frac{1.375 - d}{5.5 - d}}$$

Here d is the density of the gaseous envelope. Even gold vapor at a very high temperature would have a very low density so we may neglect it entirely for simplicity.

$$\text{Then} \quad r = R \sqrt[3]{0.25}$$

$$= 0.63 R.$$

and if the diameter 2R be 1.375×10^6 kilometers $r = 8.65 \times 10^5$ kilometers and the gaseous layer would therefore be 250,000 kilometers thick.

#1 Front

Planimeter 2·64
5·53
7·43
Mean 2·61 sq. in.

#1 Back

Planimeter 2·36
2·53
2·42
2·36
2·34
Mean 2·40

#3 Front

Planimeter 2·45
4·96
7·45
Mean 2·48

#3 Back Planimeter 2·31
4·62
6·93
Mean 2·34 sq. in.

#4 Front Planimeter 2·80
5·56
8·34
Mean 2·78

#4 Back Planimeter 2·64
5·18
7·78
Mean 2·59

#7 Back Planimeter 2·92
5·85
8·76
Mean 2·92

#7 Front Planimeter 3·17
6·35
9·52
Mean 3·18

Measurements of the activity of the Phonograph Factory Brown Engine

3rd October.

Back constant $2{\cdot}132 \times 10^{-4}$ HP Front Constant $2{\cdot}09 \times 10^{-4}$ HP
$1{\cdot}591 \times 10^{-4}$ K $1{\cdot}552 \times 10^{-4}$ K.

#1. 15·45 o'clock. Pressure $\frac{78+75}{2} = 76{\cdot}5$ 82 revs. per min. 40 opening. Front brass 4·35° Back - 4·17

Front area	2·61 sq. in.	mean coil 0·60°	= 24·6 lg per sq. in.	=	40·9 HP	Kilowatts
Back -	2·40	- - -	0·376° = 23·04 - - -	=	40·3	
					81·2	60·6

#2 15·50 $\frac{80+75}{2} = 77{\cdot}5$ 82 revs.

Front area	2·45 sq. in.	- -	0·543	22·5	=	38·4
Back	2·22		0·532	21·3	=	37·3
						75·7

56·5

#3 16·30 $\frac{75+70}{2} = 72{\cdot}5$ 84 revs.

Front	2·48		0·570	22·5	=	38·4
Back	2·29		0·549	22·0	=	39·0
						78·4

57·0

#4 ~~16·32~~ $\frac{73+70+68+65}{4} = 69$ 80 revs.

Front	2·78		0·639	23·6	=	42·6
Back	2·59		0·621	21·8	=	42·3
						84·9

63·4

#5 17·00 $\frac{80+76}{2} = 78$ 81 revs.

Front	3·00		0·690	27·6	=	46·5
Back	2·74		0·657	26·3	=	45·4
						91·9

68·6

#6 17·15 $\frac{62+59}{2} = 60{\cdot}5$ 80 revs.

Front	3·12		0·717	28·7	=	47·8
Back	2·89		0·693	27·7	=	47·2
						95·0

70·9

#7 17·28 $\frac{65+60}{2} = 62{\cdot}5$ 80 -

Front	3·08		0·708	28·3	=	47·1
Back	2·95		0·707	28·3	=	48·3
						95·4

71·2

Back constant	HP	K	Front constant	HP	K
@ 75 revs.	1·599	1·193	@ 75 revs	1·560	1·164
76 -	1·620	1·209	76	1·580	1·180
77	1·642	1·225	77	1·601	1·195
78	1·663	1·241	78	1·622	1·211
79	1·684	1·257	79	1·643	1·226
80	1·705	1·273	80	1·664	1·241
81	1·727	1·289	81	1·686	1·257
82	1·749	1·305	82	1·705	1·273
83	1·770	1·320	83	1·726	1·288
84	1·791	1·336	84	1·747	1·304
85	1·812	1·352	85	1·768	1·320

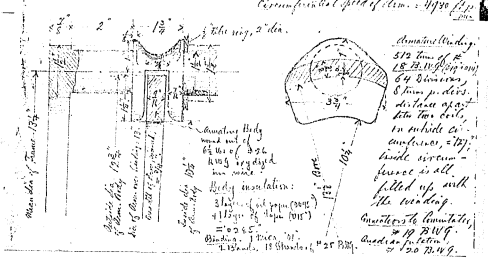
Between #3 + #4 the heat was set at work for the cylinder. This increased the current on the motor from 50 to 130 amperes = 50 × 105 = 5250 Watts = 5·25 @ 88% eff = 6·48 Kilowatts and the observed increase = 6·4.

Between #4 + #6 a number of lamps were turned on

Remounted the suspension of the Ballistic Galvanometer on the 28th September, the fibre having broken. This fibre has borne the weight of the suspended system nearly two years and the weight is 2·91 grammes. Unable to obtain any fibres from the original stock capable of lifting this weight so had recourse to a cocoon. The latter gave a good fibre tested with 3 grammes weight.

The res. of the galvanometer was 5238 ω apparent the T.B. being 24·5°C and that of the coil 19°C. The ratio coil/gal and the ind. coil/gal. 0·360 + so that the inductance of the apparatus all four coils in series = 1·886 quadrants.

½ HP. Octopolar Motor. For the Edison Dynamo. 13 Volts. 30 Amps 1400 R.P.M.
Circumferential Speed of Arm. = 4930 ft.p.m.



(exp. cotton wound (.002 + .007))

Magnet Winding: ⅞ lb of #21 B.W.G. on each of the 16 cores, making the total weight of magnet wire = 2 lbs.

Magnets connected in two parallel rows of 8.

85 turns of wire on each core. Resistance of each core = .407 ohm.

Total Magnet Resistance = 1.627 ohm.

Current in Field circuit = 2.3055 Amperes.

Magnetizing Power of each Magnet = 219 Ampere turns.

Average Field, 650 lines of force p. square inch of pole surface.

Armature – Resistance = .0128 ohm.

Electrical Efficiency = 85%.

Weight – 75 lbs. Watts p. lb = 5.

Orange N.J., June 20, 89.

A. E. Kennelly.

Calculations for the best arrangement of Lalande Battery to suit the Motor designed by Wiener for Mr Edison's tricycle.

The motor is designed for 7·5 volts. and 50 ampères. making 375 Watts. It is called a ½ HP motor and if 50 ampères be its full load current it will do most work when 15 volts are applied to its terminals. To allow for fall of potential in the battery about 20 volts ought to be applied but we will commence with 15. ÷ 0·66 = 22·5 say 23 cells of the Phonograph type. of plate which average 0·66 w. and 0·025 w paralell. The res: of 23 cells would be 0·6 w. the res: of the armature 0·0128 w Then

$$50 = \frac{15 - 7.5}{\frac{0.6}{x} + 0.0128\,w} = \frac{7.5\,x}{0.6 + 0.0128\,x}$$

$x = 5$ approximately).

So that 5 rows of 23 cells each would supply 50 ampères = 10 ampères per row. The Total energy would be 750 Watts, the work in the battery 300, in the armature 325 and the balance 417·5 would be available for use. The current in each cell would be 10 ampères, rather a heavy one.

Keeping the number of cells constant — 115 — or say 120, They might be connected in six rows of 20 each

The E.M.F. would be 13·3 volts the res: per row of 20 · 0·5w

$$13.3 - 7.5 \Big/ \frac{0.5}{6} + 0.013 = 5.8 \Big/ 0.096 = 60 \text{ ampères.}$$

Drop in battery 60 × 0·083 = 5 volts = 8·3 on terminals of motor.

Energy wasted in battery 300 Watts, in armature 47 leaving out of 798 453 for use. but 10 ampères per cell + 60 in armature

With 4 rows of 30 cells each emf. = 20 res: per row 7·5w.

$$20 - 7.5 \Big/ \frac{0.5}{4} + 0.013 = 12.5 \Big/ 0.201 = 62.2 \text{ ampères.} = 15\cdot \text{ per cell}$$

The best arrangement is evidently 5 rows of 23 cells each.

Say 20 each = 13·3 volts. res: per row 0·5w

$$13.3 - 7.5 \Big/ \frac{0.5}{3} + 0.013 = 5.8 \Big/ 0.113 = 51.3 \text{ ampères.}$$

drop in battery 5·13 = 8·17 volts left on terminals of motor.

Total energy 13·3 × 51·3 = 684 Watts in battery 262 leaving 422 available

Say 18 each = 12 volts res: per row 0·45 w

$$12 - 7.5 \Big/ \frac{0.45}{5} + 0.013 = 4.5 \Big/ 0.103 = 43.7 \text{ ampères.}$$

drop in battery 43·7 × 0·09 = 3·93 volts = 8·07 volts on motor

Energy wasted in battery 0·09 × 43·7² = 172 total energy 524

" " armature = 31 available. 203 / 321

The magnet will take 20 leaving 300 Watts.

The safe limit will thus be 5 rows of 18 cells each.

Street Car Electrical Railroad data

If cars run every quarter of an hour each way on a double track at the average rate of 5.5 miles (5250 ft) per hr = 29,000 ft per hour = 7250 feet apart, and if every ten minutes 4830 feet apart.

On the Orange Railroad of the routes crossing each other (from Washington St. and in Valley Road to the limit of Prospect St. in Orange and from Roseville avenue to Fremont avenue there would be some 31 transformers 600 feet apart = 18600 feet of road = 37200 feet of track and 9 cars would be running. Each car might absorb on the average 5 kilowatts and @ 60% efficiency 12.6 amperes from the main circuit. There would then be 114 amperes actively employed and about 20 transformers would be idle each absorbing 2 amperes say = 40 amperes making a total of 154 amperes which with leakage might be 160 amperes 160 amperes @ 1200 volts 192,000 Watts.

If cars run every 5 minutes they will be 2400 feet apart and 16 would be on the track = 200 amperes actively employed and about 16 transformers idle = 32 amperes making a total of 232 amperes which with leakage might reach 240.

One main feeder running south might supply the transformer mains at about Central Ave. Bonus being 7000 feet in length. It might be assumed to supply transformers 24 to 31 = 11 transformers half of which are on full load = 69.3 amperes and the other half take 2 amperes each = 11 amperes = 80. amperes to be carried 7000 feet and if 1100 volts be applied at transformer terminals 1150 volts might be allowed for supply at transformer mains = 50 volt drop in mains. The dimensions of the wire are now to be determined.

If r be the res. per foot of the wire 800 = the drop per foot and 560,000 = d the drop in the whole feeder.

for d = 50	$r = \frac{1}{11200}$	8.9×10^{-5}	0.0000089	0.346
= 100	$r = \frac{1}{5600}$	1.78×10^{-4}	0.0000178	0.245
= 150	$r = \frac{1}{3730}$	2.68×10^{-4}	0.0000268	0.200
= 200	$r = \frac{1}{2800}$	3.57×10^{-4}	0.000357	0.173 about #7 B&S.

So that on this feeder if the ground be used as a return circuit #7 wire would carry the load if supplied at the station somewhere near Park Ave. & Park Place with 1350 volts.

A second feeder about 1500 feet long would supply transformers 1 2 3 4 5 6 14 15 16 17 18 19 & 20 = 12 in all the current would be 75.6 + 12 = 87.6 amperes say 90. d = 1350000

d = 50	$r = \frac{1}{2700}$	3.7×10^{-4}	0.000370	0.158 #8
= 100	$r = \frac{1}{1350}$	7.41×10^{-4}	0.000741	0.122 #11 B&S.
= 150	$r = \frac{1}{900}$	1.11×10^{-3}	0.00111	0.095
= 200	$r = \frac{1}{675}$	1.4814×10^{-3}	0.001148	0.079 about #13 B&S.

As this is much too small a wire we can take a #8 wire and allow a heavier drop in the mains over this section of the line.

A third feeder about 4500 feet would join Dodd St about Glenwood ave. and supply transformers 6 to 13 = 8 = 60 amperes

d = 290,000.

for 50 volt $r = \frac{1}{5400} = 1.852 \times 10^{-4} = 0.000185$ 0.234

100 " $r = \frac{1}{2700} = 3.704 \times 10^{-4} = 0.000370$ 0.173 #7 B&W.

150 " $r = \frac{1}{1800} = 5.56 \times 10^{-4} = 0.000556$ 0.141 #9.

200 " $r = \frac{1}{1350} = 7.41 \times 10^{-4} = 0.000741$ 0.109

As 100 volts drop in the feeder answers very well for the Northern and central line the southern feeder may be divided into two, one to feed transformer 27–31 5 at a point close to Highland Ave. station and the other the remaining 20 – 27 = 8. The current on the former would be 31.5 + 5 = 36.5 amperes its length 8700 feet that on the latter 60 amperes 5000 feet joining at Henry St.

for the former d = 317,550.

for 100 volt $r = \frac{1}{3175} = 3.146 \times 10^{-4}$ 0.000314 0.173 #7 B&W.

for the latter d = 300,000

for 100 volt $r = \frac{1}{3000} = 3.33 \times 10^{-4} = 0.000333$ 0.173 #7 B.W.G.

So that we have south #1 8700 feet of #7 B.W.G.

#2 5000 - - - -

centre #3 1500 - - 11 - -

north #4 4500 - - 7 - -

giving a total of 147,000 feet of #7 B.W.G. and 1500 feet of #11 B.W.G. using the ground as a return 1450 lbs of #7 and 100 lbs #11.

The mains have now to be determined

For the south #1 the center of distribution will be 1000 feet 18 amperes, and d = 18,000 for 50 volt $r = \frac{1}{360}$ $2.78 \times 10^{-3} = 0.00278$ 0.070" diam = #18 B.W.G.

For south #2 the center of distribution will be about 1000 feet 30 amperes d = 30,000 for 50 volt $r = \frac{1}{6000} = 1.67 \times 10^{-3} = 0.00167$ = 0.059 #18 B.W.G.

For central #3 the center of distribution will be about 1500 feet south and 5% transformers and about 2000 feet north 7% transformers (36.5 and 51 amperes respectively). This will mean

S. d = 54,700 r for 50 volt $r = \frac{1}{10904} = 9.0 \times 10^{-4} = 0.00009$ = 0.109" #12 B.W.G.

N d = 102,000 - 50 r $\frac{1}{20410} = 5.0 \times 10^{-4} = 0.0005$ = 0.141" #9 B.W.G.

We should thus have 18600 feet of #9 B.W.G. weighing 1200 lbs.

Test of faulty one milling pick off magnet

Res. of circuit 11.63 ω lead 2.55 magnet 9.28

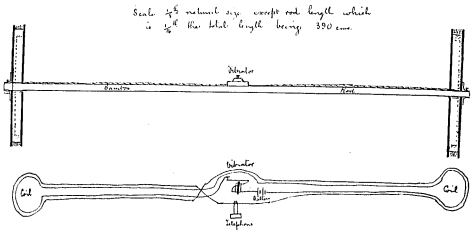
added 4 bulb 100% 100% ω

Distance of ground 1.5050 from heating table

lead 1.175

.33 ω

.33 ÷ 0.0043 = $\frac{330}{4.3}$ = 80 feet.



Measurements of the Inductance in the 12-foot pole induction balance for having iron ore.

4 layers each of about 105 cms circumference (mean) of #24 silk covered wire 0.022" (0.055 cm) were wound on the thin wooden rod shown in section. These layers were doubly wound with 15 turns each = 30 turns in all, or 6300 cms in each circuit. The following measurements were made with the coils.

No.	Ratio Coil Bridge	Res. Ohms	Condensers	Diff. Inductances Gradiants	Diff. Inductances Kilometers	Mutuals Gradiants	Mutuals Kilometers	Differential Mean for Kilometer
1	1000/100 A	7.520	0.665	0.0050	50.02			
2	TB 25.5° B	7.290	0.685	0.0050	49.92			
3	B+A	7.300	0.700	0.0051	51.10	-	0.58	0.4455
4	B-A	7.300	0.675	0.00449	49.21	-	0.33	

Obtained a good balance with the two coil by altering the winding. On taking the apparatus out to the ore pile. It was found that exciting by 3 Grenell Bunsen cells powerful effect could be obtained with big iron pipes at the ore when one bobbin was close up to it but the limit of intensity was very narrow and two feet away it was imperceptible.

Borsilate Tests

Received from Mr Hutchinson on the 3rd October several samples of borsilate for further tests.

Sp: gr: 1.4438 @ 22° C.

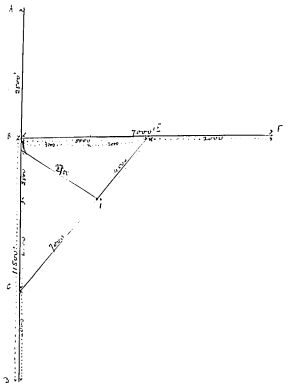
1 piece was exposed to rain + sun for two days in the open air and then placed in water for 5 days more. It showed slight softening and it was observed to be practically o.k.

#2 piece placed on boiler and exposed to temp. of 150°F for seven days. Behavior perfect

#3 piece was used as a lamp socket for 8 days + kept in a box at about 210° F. (100°C) no bad results observed

#4 piece buried about 4" in moist earth, under gutter. This piece showed mouldy condition and was very brittle.

# 5	specimen immersed in	$C_{10}H_{16}$ turpentine		not attacked
# 6	- - -	conc. C_4H_6O	not attacked cold but temporarily softened on heating	
# 7	- - -	cold water H_2O	- - -	on boiling temporarily softened
# 8	- - -	$NaHO$ 1.2 sp. g.	became red paste and dissolved in 45 minutes	
# 9	- - -	H_2SO_4 50%	-	slightly softened. Dissolved with decomposition on boiling
# 10	- - -	conc. HNO_3	attacked cold + totally dissolved on boiling	
# 11	- - -	$C_6H_8O_7$	- -	-
# 12	- - -	NH_4HO	- -	-
# 13	- - -	sol. $NaCl$ 20%	after 20 hours superficially softened	
# 14	- - -	weak sol. $NaCl$ to imitate sea water	slightly softened but still quite serviceable after 5 days	



Street Car Railroad Data
on 250 volt conduit system.

Cars assumed to run every 5 mins, and consequently to be 2400 feet apart, at average speed of 5.5 miles per hour. Each car to be supplied with 5 Kilowatts on the average. Taking the same Orange district there would be 21000 feet of distance + 42000 feet of track.

The motors will be wound for 220 volt terminal P.D. and if worked at an efficiency of 75% on average load, their e.m.f. will be 165 volts. To absorb 5 kilowatts they will take 30.3 amperes, including magnetizing current say 32 amperes. There will be 6 cars on the eastern route, two on the northern, 10 on the southern. The eastern section will thus take 192 amperes, the northern 64, the southern 320. Total 576 - Here Kilowatts. On this basis the drop between station and car on feeders and mains would be 20 volts = 12.%. The feeders would be Edison tubes and the mains would be conduits. A drop of 20 volts might be permitted in the feeders and 10 volts in the mains.

The southern feeder as on page 66 would be 7000 feet long
" central " " " " " 2700 " "
" northern " " " " " " 4500 " "

On the main AD there would be ~~4 x 7.2~~ = 138 amperes at 2000 feet distance ∴ $\frac{276000}{2} \times r = 10$ ∴ $r = \frac{10}{138000} = \frac{1}{13800} \times 10^{-4} = 1000 \times 7245$ = 15,000 cmil. 150,000 cmil on each track - #150 tube conductor.

Feeder 1C will carry 276 amperes say 280 and being 7000 feet in length $280 \times 7000 \times r = 20$ ∴ $r = \frac{2}{280 \times 7000} = \frac{1}{980000}$ 1000000 cmil #1000 tube.

Feeder 1B will carry 8.5 x 7.2 = 262 amperes and being 2700 feet in length can also be #360 tube.

Feeder 1E will carry 129 amperes and being 4500 feet in length can also ~~being~~ #260 tube.

~~There will there be 14,200 feet of #20 feeder = 284,000,000 cmil feet.~~
~~= 862 say 900 lbs in all.~~

~~There will also be 42,000 " " #30 main = 1,260,000,000 cmil feet~~
~~= 3780 say 4000 lbs in all.~~

There will there be 40,000 ft of #150 conductor = 6000,000,000 cmil ft
= 18000 lbs.

7000 " " 1000 " = 7000 million cmil ft
= 21000 lbs.

2700 " " 360 " = 972 " "
= 3000 lbs.

4500 " " 260 " = 1170 million cmil ft
= 3500 lbs

Total 45,500 lbs copper.

Comparison of the Transformer and Direct Systems of Street Car Railroad Operation on the specimen Orange Route.

Transformer

Plant. In addition to Cars motors + track.
Central Station

Dynamos to supply 280 a @ 1250v
Energy 300 Kilowatts (400 H) supplied
Engine developing 333 Kilowatts 446 H. P. @ 20%
Time 18 hrs daily 6000 Kwhrs 8000 H hrs @ 25¢
= $1200.00 daily = $73,000 annually, — $73,000

31 Transformers @ $1000 = $31,000
interest + depreciation @ 10%. — 3,100

Lines Feeder 14,700 ft. # 7 B&S.
2000 " # 10 "
= 16.00 lbs of copper @ 25¢ $4.00
Int + depreciation 10% — 40

Mains in Primary system
18,600 feet of # 9 B&S. 120 lbs copper
@ 25 ¢ = 300 $. int — 30

Secondary mains second to track
19000 ft @ $1.20 per ft. $23,000
int + depreciation 15% — 3,450.

Power + conductors annually $79,620

Energy Account.

	Watts
18 cars averaging 5 kwh each	90,000
Loss in motor armature	15,000
" " rails	5,000
" " transformer secondary	18,000
" " " primary	22,000
" " friction in transformers	60,000
" " primary main feeder	15,000
	300,000
" " dynamos + shafting	32,000
Energy developed at engine shafts	333,000

nett efficiency of system 27%

Direct.

Plant In addition to Cars, motors, + track.
Central Station

Dynamos to supply 580 amp @ 250 v.
Energy 145 Kilowatts 193 H. supplied
Engine developing 192 Kw. 215 H @ 30%
Time 16 hrs daily 2900 Kwhr. 3870 H hrs @ 25¢
= $ 97.00 daily = $35,400 annually — $35,400

40,000 ft. of # 150 E.G. conduit conductor
@ $1.75 per ft = $70,000
Int. + dep. @ 15% — 10,500

7000 ft of # 1000 E.G. feeder
= 3 lbs copper per ft @ 25¢
= $525.00 10% — 5,250

2700 ft of # 360 E.G. feeder
1.1 lbs copper per ft @ 25¢
$150 — 750

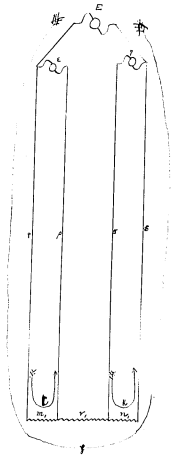
4500 ft of # 240 E.G. feeder
0.8 lbs copper per ft @ 25¢
$900 — 900

Power + conductors annually $52,800

Energy account

	Watts
18 cars averaging 5 kwh each	90,000
Loss in armatures	30,000
" " magnets	5,000
" " conduit	5,000
" " feeder.	12,500
	142,500
" " dynamos + shafting	16,000
Energy developed at engine shafts	161,000

nett efficiency of system 56%



Mathematical Examination of System about to be patented by Mr Edison

October 15th 1889.

Let E be the e.m.f at terminals of main supply
" ε " - - - - - - left "
" η " - - - - - - right "
" ρ - - common pressure at feeder extremities.
" m - - number of lamps on left hand
" n - - - - - - right -
" r - - - - - in centre.
" γ - - main current from E
" ε - - left hand circulation through c
" κ - - right - - - η

Required for a given system of feeder of resistances r ρ σ and s the emf necessary for E ε and η when m n and r are varied in any manner, the resistance of any lamp being l.

Also let $m_1 = \frac{l}{m}$ $n_1 = \frac{l}{n}$ $r_1 = \frac{l}{r}$

Then
$$E = (\gamma+c)(m_1+r) + \gamma r_1 + (\gamma+k)(n_1+s) = \quad (1)$$
$$\varepsilon = (\gamma+c)(m_1+r) + c\rho \quad (2)$$
$$\eta = (\gamma+k)(n_1+s) + k\sigma \quad (3)$$

$$\therefore \quad E = (\gamma+c)r + (\gamma+k)s + 3\rho \quad (4)$$
$$\varepsilon = (\gamma+c)r + c\rho + \rho \quad (5)$$
$$\eta = (\gamma+k)s + k\sigma + \rho \quad (6)$$

Also if $il = \rho$ then $c + \gamma = \frac{mi}{l}$ $\gamma = ri$ $\gamma + k = ni$ (7)

$$E = mir + nis + 3\rho \quad (8)$$
$$\varepsilon = m_1 ir + (m_1 - r_1)i\rho + \rho \quad (9)$$
$$\eta = n_1 is + (n_1 - r_1)i\sigma + \rho \quad (10)$$

Suppose $m = n = r$ (10a)

$$E = m_1 ir + m_1 is + 3\rho \quad (11)$$
$$\varepsilon = mir + \rho \quad (12)$$
$$\eta = mis + \rho \quad \therefore E = \eta = \tfrac{2}{3}(r+s+\rho)(13)$$

Suppose $m_1 = 0$ $\therefore m_1 = \infty$

$$E = nis + 3\rho$$
$$\varepsilon = -rip + \rho$$
$$\eta = nis + (n-r)i\sigma + \rho$$

Suppose $r = 0$

$$E = nis + 3\rho$$
$$\varepsilon = \rho$$
$$\eta = nis + ni\sigma + \rho$$

And for any given values of m and r there correspond only one definite set of values for E ε and η.

Suppose m = a large number in great excess

$$\left.\begin{aligned} E &= Mir + nis + 3\rho \\ \varepsilon &= Mir + (M-r)i\rho + \rho \\ \eta &= Mis + (n-r)i\sigma + \rho \end{aligned}\right\} \varepsilon > \rho$$

Suppose r = N a large number

$$\varepsilon = m(r+\rho) - N\rho + \rho \qquad \eta = ni(s+\sigma) - Ni\sigma + \rho$$

If $N\rho > m(r+\rho)$ $\varepsilon < \rho$. + If $N\sigma > n(s+\sigma)$ $\eta < \rho$

So that ε will be $< \rho$ when $\frac{r}{m} > \left(1 + \frac{\rho}{r}\right)$

η - - $< \rho$ - $\frac{r}{n} > \left(1 + \frac{\sigma}{s}\right)$

General formula for determining the dimensions of power mains.

If l be the length of the conductor (to and fro)
" ρ " " res: per unit volume (resistivity) ohms
" a " " area
" d " " diameter
" v " " pressure of supply (volts)
" δ " " of drop in the mains
" ε " " energy to be supplied

Then the pressure of arrival is $v\left(\frac{100-d}{100}\right)$
" current is $\frac{\varepsilon}{v}\left(\frac{100}{100-d}\right)$

$$\therefore \quad \frac{vd}{100} = \frac{\varepsilon}{v}\left(\frac{100}{100-d}\right)\frac{4l\rho}{\pi d^2} = \frac{\varepsilon}{v}\left(\frac{100}{100-d}\right)\frac{l\rho}{a}$$

$$a = \frac{\varepsilon}{v^2}\left(\frac{10{,}000}{100-d}\right)\frac{l\rho}{d} \qquad (1)$$

If ρ be taken as $1{\cdot}7 \times 10^{-6}$
then a will be in sq: cms.

Or if ρ be taken as 10 and l be given in feet
a will be in circular mils

$$\therefore \text{cmils} = \frac{100{,}000\ \varepsilon\ l}{v^2 d\ (100-d)}$$

$$\text{cmils} = \frac{10^8\ \varepsilon\ l}{v^2 d\ (100-d)} \quad \text{where } \varepsilon \text{ is in h.p. watts} \qquad (2)$$

Since a cmil foot weighs $3{\cdot}015 \times 10^{-6}$ lbs.

$$\text{weight per foot } w = \frac{3{\cdot}015\ \varepsilon l \times 10^{-2}}{v^2 d\ (100-d)}. \qquad (3)$$

and total weight W = $\frac{3{\cdot}015\ \varepsilon\ l^2 \times 10^{-2}}{v^2 d\ (100-d)}$ lbs. (4)

$$= \frac{13{\cdot}46\ \varepsilon\ l^2 \times 10^{-4}}{v^2 d\ (100-d)} \text{ tons} \qquad (5)$$

Calculation of the dimensions of conductor required to transmit power from Niagara to Buffalo. a distance of seventeen miles

89,760 feet (say) 90,000 feet (1) (using ground return)

Let the P.D. at dynamo terminals = 6000 volts. (v)
" drop in this line be d %.
Then if there be negligible leakage
" let ε be the power to be transmitted (watts)
" c " " current in the line (amperes)
" δ " " drop in the line. (volts)
" k " " conductance of 1 cmil ft. (mhos)
" n " " no: of cmils.

Then $(v-\delta)c = \varepsilon$

$$\therefore c = \frac{100\varepsilon}{100v - dv} = \frac{\varepsilon}{v}\left(\frac{100}{100-d}\right)$$

$$\delta = cr = c\left(\frac{1}{nk}\right) = \frac{cl}{nk} \quad \therefore$$

$$\delta = \frac{dv}{100} = \frac{cl}{nk}$$

$$\therefore n = \frac{100cl}{kdv}$$

$$= \frac{100\,l}{d\,kv^2}\frac{\varepsilon}{}\left(\frac{100}{100-d}\right) = \frac{10{,}000\ l\varepsilon}{d\,(100-d)\,kv^2}$$

Let $d = 15$ $v = 6000$ $l = 90{,}000$ $\varepsilon = 150{,}000\,\text{HP} = 112{,}000{,}000$ $k = 0{\cdot}1$

$$= \frac{1{\cdot}0 \times 10^4 \times 9{\cdot}0 \times 10^4 \times 1{\cdot}12 \times 10^8 \times 1{\cdot}0 \times 10^2}{15 \times 10^1 \times 1{\cdot}0 \times 10^{-1} \times 6{\cdot}0 \times 6{\cdot}0 \times 10^7 \times 5{\cdot}5 \times 10^1}$$

$$= \frac{10{\cdot}08 \times 10^{14}}{459 \times 10^7} = \frac{10{\cdot}08 \times 10^{14}}{4{\cdot}59 \times 10^9} = 2{\cdot}20 \times 10^7$$

$= 22$ million cmils.

For 150,000 HP = 112,000 watts = 22,000 amperes.
" 20,000 HP = 15,000 " = 3000 " approx.

$$= \frac{40 \times 10^4 \times 9{\cdot}0 \times 10^4 \times 1{\cdot}5 \times 10^2}{4{\cdot}59 \times 10^9} = \frac{13{\cdot}5 \times 10^{14}}{4{\cdot}59 \times 10^9} = 2{\cdot}94 \times 10^6.$$

36·75 #8 B.W.G. wire makes 1 million c. mils.
110 #3 " " " 3 " " "

$2{\cdot}94 \times 10^6 \times 9{\cdot}0 \times 10^4 = 26{\cdot}46 \times 10^{10} = 2{\cdot}646 \times 10^{11} \times 3{\cdot}015 \times 10^{-6}$ lbs

$= 7{\cdot}978 \times 10^5$ lbs
@ 20 c per lb
$= 159{,}56 \times 10^2$ \$
$= \$159{,}560$

Electrolytic determination of the Ohach Ring Constant. after removing suspension on a single cocoon fibre. 14. X. 82.
The weight of the suspension (needle, weight, stem + points) 2·34 g.

Silver plating in 25% solution $AgNO_3$ almost neutral.

Weight before heat (1) 15·6110
(2) " 19·2275

Current of about 2 amperes passed for just 300 seconds
Deflection 0·1400, 0·399, 0·1400 } 0·3997

Weight after heat (1) 16·2850
(2) 17·5450

$+ 0{\cdot}6740 \quad - 0{\cdot}6825$

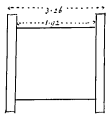
$0{\cdot}6782$

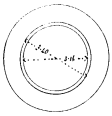
$0{\cdot}00111182 \times 300 = 0{\cdot}33546$

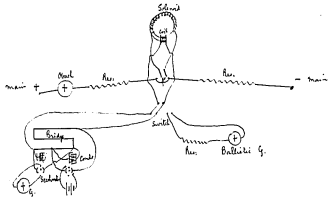
$= 2{\cdot}022$ amperes

$= 0{\cdot}1977$ per ampere. $\left(\frac{1}{5{\cdot}058}\right)$

Galvanometer gives equal deflections on each side within limits of obs.







$56.36 \times \frac{2}{3} = 37.57$ mm length of coil

$642 \div 37.57 = 17.09$

$17.09 \times 1.257 = 21.48$

Permeability Measurements.

October 16th & 17th

Set up the Ballistic galvanometer and took two series of permeability measurements with the Norway iron ring described on page 61. The first series could not be directly interpreted owing to the inertive condition of the galvo. subsequently brought to notice. The magnetic system was found to have like poles. The suspension was then taken down + remagnetized. Indirectly however from the results of the second series, the first are obtainable.

A small wooden reel of hard wood made in two halves was placed on the iron ring in the center of the space unoccupied by the winding, and it was then wound with fine silk covered wire. On the first layer there were 51 turns, on the second 52, on the third 53, on the fourth 52, on the fifth 51 and on the outermost 50 making 309 turns in all, tissue paper being laid between each layer. This wire was #30 S.W.G. 0.012" diam. covered to 0.014".

The following are the results of series #1.

Obs. No.	Deflection of Normal galvo	Amperes	Deflection Throw on Ballistic at Shunt	Res. of Ballistic at Shunt	a	φ	Σ	H	μ	Res. coil alone	Resistivity for volume	Induction K.Kilomaxwells
1	0 Switch									13.52	0.225	30.42
2	0.060	0.054	29.5	5300			1310	1.16		13.55	0.220	29.81
3	0.094	0.084	65.5	"			2900	1.81		"	"	29.81
4	0.191	0.171	141	"			6250	3.67		13.55	0.200	27.10
5	0.340	0.304	203	"			8990	6.53		"	"	27.10
6	Shunts 0.212	1.083	311	"			13770	23.26		13.57	0.155	21.03
			119.4	13700			13670			—	—	21.03
7	0.453	2.292	736	"			15570	49.24		13.57	(0.135) (1.50)	18.32 20.35
8	0.588	2.974	1411.5	"			16200	63.89		13.67	1.390	19.00
9	0.810	4.097	1145	"			16600	88.00		13.67	1.270	17.36
10	1.223	6.185	1148.5	"			17000	132.9		13.82	1.120	15.48
11	2.04	10.32	1547	"			17110	221.6		13.87	1.030	14.29
12	1.195	6.043	1148.3	"			16980	129.8		14.56	1.800	16.02
13	0.755	3.919	1144	"			16490	82.04		14.65	1.200	17.58
14	0.363	1.936	126.2	"			15600	39.44		14.82	1.460	21.64
15	0.200	1.011	122.3	"			14200	24.71		14.77	1.780	26.29
16	1.157	0.794	114.2	"			13070	24.06		14.53	1.852	26.88
17	0.109	0.506	97.5	"			11380	10.87		14.32	2.180	31.21
18	0.313	0.280	257	5300			9260	6.015		14.26	2.280	32.51
19	0.195	0.175	209	"			6960	3.76		14.15	2.80	39.61
20	0.100	0.086	155	"			3370	1.85		—	—	39.61
21	0.050	0.043	76	"			12.00	.975		14.00	2.75	38.55

* Bridge ratio changed from 1000/1000 to 100/100.

Temp.: Ballistic Galvo 74°F 23.3°C T.B. 27.2°C.

There is very great uncertainty in taking the value of a from the ballistic throw with Σ less than 7000 for with a needle whose period is 12 seconds, the discharge continues at diminishing rate during several periods which H is below 14. Above these values the induction becomes more decided, and rapid.

$$1.6285 \times 10^{9} \times 1.0 \times 10^{-15} = 10\mu \text{ dis}$$

$$(\phi) \quad \therefore \quad 1.0 \times 10^{-7} = 72.8 -$$

$$1.511 \times 10^{-7} = \frac{3.09\ \varphi \times 10^{2}}{3.03 \times 10^{9}} = \frac{1}{0.9802 \times 10^{n}}$$

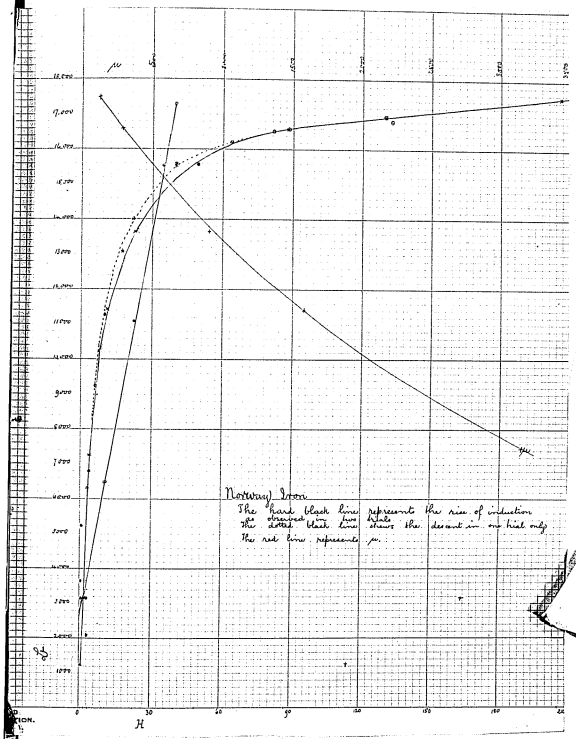
$$\therefore \quad \varphi = \frac{3.03 \times 1.511}{3.09} \times 10^{5} = 1.482 \times 10^{4}$$

$$\frac{4\pi nc}{\frac{C}{a\mu}} = \mathcal{E} \qquad \therefore \quad \frac{1}{\mu} = \frac{4\pi nca}{C\mathcal{E}}$$

$$\rho = \frac{1}{\mu} = \frac{1.257 \times 6.442 \times 6.02 \times \text{amperes}}{56.36\ \varphi}$$

$$= \frac{86.2\ a}{\varphi}$$

$$\mu = \frac{1.16\ \varphi}{100\ a} = \frac{1.927\ \varphi}{10\ a}$$



Determination of Galvanometer Constants.
by Silver Electrolysis

October 16th. The fine wire coil of the Obach Galvr, the fine wire coil of the Dumoncel Galvr + the fine wire coil of the Gaugain galvr were connected in series with a battery and a silver voltameter.

The weights of the plates were (1) 16.2650 (2) 17.5390

+ after heat (1) 16.5255 (2) 17.2760

+0.2605 −0.2630

0.2618

The current was flowing during 136 g mins (821140 seconds)

The deposit per second would be 0.000003187 g. = 0.000285 amp

The mean Obach deflection was 1.21 ± = = 0.42405

" " Dumoncel " " 52.' ± = tan⁻¹ 1.27994 = 0.44490

" " Gaugain " " 15°15' ± = tan⁻¹ 0.27263 = 0.09562

Previous determinations Sept. 12th 1888 made these constants 0.398 0.46874 and 0.0951 respectively, discrepancies −6.5 · +4 and 0.7% respectively.

A comparison between the Einheit + the Obach gave 3.2 divs. equivalent to 1.215 on Obach scale = 2.863 so that the reduction factor for the Einheit is thus 0.89446 or it overestimates 11.8%

On the 13th Sept. 1888 the Obach fine wire constant gave = 0.40445

" " Dumoncel " " " = 0.42286

in ratio to those of 0.9528 and 0.9546 respectively.

Permeability Measurements continued.

October 17th. Second series after remagnetising ballistic needle.

No. of Obs.	Mean ext. Galvr. Defl.	Amperes	Mean Ballistic throw	q $\times 10^{-5}$	$2q$	2π	Flux total in Ballistic est.	H	μ	ρ	Flux of outer tube	Capacity for Inductn	Induction Kilomaxwells
1	0 Einheit	0	0								13.47	3.0	40.41
2	0.050	0.045	111	1.511	1.4824	2460	39,300	0.967	1919		13.47	2.70	36.34
3	0.093	0.083	291.5	4.004	3.926	6520	"	1.783	2740		13.48	2.90	39.08
4	0.179	0.160	1355	4.876	8.727	14,500	58,300	3.437	3160		13.48	2.80	37.75
	Obach		186	2.555	9.708	16,470	205,200						
5	0.100	0.506	294	4.038	13.76	22,860	"	10.87	1580		13.48	2.40	32.35
6	0.208	1.052	180	2.472	16.43	27,290	205,300	22.60	906		13.48	1.95	26.29
7	0.370	1.976	205	2.816	18.71	31,080	"	40.30	578		13.50	1.58	21.30
8	0.811	4.102	219	3.008	19.98	33,180	"	88.14	283		13.50	1.30	17.55
9	1.940	9.608	231.5	3.180	21.13	35,100	"	206.4	129		13.83	1.04	14.39

I Clark cell both before and after series gave throw of 104 divs ± thus it @ 23.5°C. = 1.4285 microvolts. = 72.9 divs per microvolt

The values of μ here obtained compare with Hopkinson's as follows

h	Ours	Hopkinson	h	Ours	Hopkinson	h	Ours	Hopkinson
8000	2900	2520	13000	1110	1100	17000	205	190
9000	2470	2270	14000	850	820			
10000	2050	2000	15000	620	570			
11000	1710	1700	16000	400	310			
12000	1400	1410						

Measurement of the Galvanometer Constants by Electrolysis

October 19th 1889

Arthur Lehmann.

Ohach fine wire coil in circuit with the Bunsen.
Same silver plates + 25% solution

Weight before test	#1	16.4090	
	#2		17.2602
Test lasted 23 hrs = 82800 sec			
After	#1	16.6698	
	#2		16.9962
		0.2608	0.2640

Mean Ohach deflection 1.2076
Bunsen 3.089 milliamperes.

$0.26210 / 82800 = 2.624 \times 10^{-7} / 0.828 \times 10^{5} = 3.17 \times 10^{-6}$ $\quad 0.26210$

$3.17 \times 10^{-6} \div 1.11815 \times 10^{-3} = 0.002834$ amperes.

Ohach constant $1.2076 / 2.8334 = 0.4261$ per milliampere. (factor 2.347)
Bunsen $3.089 / 2.8334 = 1.090$ " " (" 0.9174)

On the roughly estimated cost of transmitting power from Niagara to a factory 3 miles distant! (say 16000 ft)

By formula on page 72

$l = 32000$

$E = 15{,}000$ (20,000 #)

$d = 20$

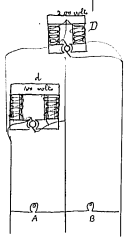
$v = 800$

$$\# W = \frac{1.346 \times 1.5 \times 10.24 \times 10^{11}}{6.4 \times 10^{5} \times 1.6 \times 10^{3}} = \frac{2.019 \times 1.024 \times 10^{11}}{10.24 \times 10^{8}} = 2019 \text{ tons}$$

= @ \$ 450 per ton \$900,000 dollars roughly.

Dynamo test for a new form of 3 wire System 19th October 89.

Trial the following arrangement



D is a 200 volt dynamo
d " 100 " "

The field magnets of D are so connected with the feeders that a short circuit on A takes the current off one limb and a short circuit on B takes the current off the other limb, thus keeping the pressure down to 100 volts.

A short circuit at B had the desired effect the lamp A flickered brightly and then resumed normal illumination.

A short circuit at A did not succeed in lowering the P.D. on B more than 20 volts leaving 180 there. This was due to the fact that the fields were not nearly saturated and 200 volts on the ~~left~~ right hand limb nearly had the same effect as 200 volts on both limbs.

Resistance was thrown into the right hand limb circuit till the machine would just excite but the reduction expected did not take place 160 volts being still left on B, but there is little doubt that if the magnets had been nearer saturation the plan would have succeeded.

Test of Car Brake Motor.

This motor has its armature shaft on centres and fitted with a worm of pitch. This worm engages in a toothed wheel on a vertical axis. Above this toothed wheel of radius " fits a friction cast iron disk whose rim has a radius of 4.8". This disk also has spurs and a chain at a radius of 6.0" running about 30" to a smaller sprocket on the ordinary brake shaft. The small spur wheel has a radius of 1.94" so that the power is multiplied 3.1 times. A drum was fitted to the vertical shaft had a rope attached to it at one or two different radii and the rope ran over a pulley down to a box of weight. By observing the current and p.d. on the motor and also the weight lifted and leverage a rough test of the efficiency was obtained. Thus calling the weight p the effective lever radius l" the spur ratio 3.1 and the observed angular velocity of the spur disk ω, the power delivered by the machine in addition to its own friction and the friction at pulley + shaft bearing $= \frac{3.1 p l \omega}{8660}$ watts $= 3.58\, p l \omega \times 10^{-4}$

1st trial p 32 lbs
l 27"
ω 0.405
$p + 32$ lbs $= 64$ lbs; $w = 125$; 0.165 HP
43 volts + 11.5 amperes = 495 Watts
Nett efficiency 25 % 0.25

2nd trial p 52
l 28.3
ω 0.340
$p + 32$ lbs $= 84$ lbs; $w = 171$; 0.239 HP
42 volts + 12 amperes = 504 Watts
Nett efficiency 34 % 0.34

3rd trial p 25.8
l 21.5
ω 0.385
$w = 76.5$; 0.10 HP
46 volts + 10.5 amperes = 483 watts
Nett efficiency 15.9% 0.16

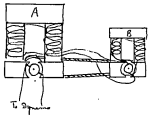
4th trial p 35.8
l 26.5
ω 0.425
$w = 144$; 0.19 HP
46 volts + 11 amperes = 506 Watts
Nett efficiency 28 % 0.28.

5th trial running light $\omega = 0.523$ .52 volts + 8 amperes = 416 Watts.

Description of an Experiment

Made on the 29th October of the starting power of motors when their field magnets are not supplied.

The 200 volt dynamo (#2 sig. wound for 200 volts) was connected up through adjustable resistance, and by means of its pulley a small 750 Watt machine was driven in such a manner as to react and supply its field magnets. It was found that about 80 amperes were necessary to start the 200 volt machine under these conditions. It then rapidly acquired speed and in ten seconds from the time of making contact had raised the e.m.f. of the small dynamo up to and even beyond the normal.



A 200 volt dynamo armature supplied by 90 amperes running as motor driving B an dynamo which in turn excites both fields.

When the belt was removed about 75 amperes was required.

With the Municipal 16 amp. machine under similar circumstances about 25 amperes was sufficient for the first 2 trials to start it. After that 40 amperes were failed

On the cost of copper required to transmit 20 000 HP from Niagara to Buffalo.

The distance is taken at 17 miles direct or 20 miles including the returns to grounds. The P.D. at dynamo terminals to be 6000 volts. The price of copper to be 19 cents per lb. or $4.25.50 per ton in wire. No leakage assumed.

The formula by page 72 is $W = 0.1346\, E^2 / v^2 d\,(100-d)$

Here $l = 1.056 \times 10^5$ $\quad l^2 = 1.115 \times 10^{10}$

$E = 1.5 \times 10^4$

$v = 6.0 \times 10^3$ $\quad v^2 = 3.6 \times 10^7$

$$\left.\right\} W = \frac{6.25 \times 10^5}{d\,(100-d)} \text{ lbs.}$$

% drop	HP generated	Tons of copper	Investment in copper	% drop	HP generated	Tons of copper	Investment in copper	% drop	HP generated	Tons of copper	Investment in copper
5	21,050	1320	562,000	18	24390	424	181,000	31	28960	292	124,000
6	21,180	1110	472,000	19	24690	407	173,000	32	29410	287	122,000
7	21,500	962	409,000	20	25000	391	166,000	33	29850	282	120,000
8	21740	847	360,000	21	25320	377	160,000	34	30300	279	119,000
9	22,000	764	325,000	22	25640	364	155,000	35	30770	275	117,000
10	22,200	694	295,000	23	26000	353	150,000	36	31250	271	115,000
11	22,470	640	272,000	24	26320	342	146,000	37	31750	268	114,000
12	22,730	592	252,000	25	26670	333	142,000	38	32260	265	113,000
13	22,990	552	235,000	26	27030	325	138,000	39	32790	263	112,000
14	23250	518	221,000	27	27400.	317	135,000	40	33330	260	111,000
15	23520	490	209,000	28	27770	310	132,000				
16	23810	465	198,000	29	28170	304	129,000				
17	24100	442	188,100	30	28570	298	127,000				

Taking the investment per HP at $28 we have.

% drop	HP gen.	Copper invested	Total investment	%	HP gen.	Copper invested	Total Investment	%	HP generated	Copper invested	Total investment
10	621,600	295,000	916600	15	658,840	209,000	867,840	20	700,000	166,000	866,000
11	629,160	272,000	901,160	16	666,680	198,000	864,680	21	708,900	160,000	868,000
12	637,440	252,000	899,440	17	674,800	188,000	862,800	22	718,000	155,000	873,000
13	643,720	235,000	878,720	18	682,920	180,000	863,920	23	728,100	150,000	878,000
14	651,000	221,000	872,000	19	691,200	173,000	864,200	24	737,000	146,000	883,000

So that for 6000 volts at machine terminals, 20 miles of line copper at 19 cts per lb. and the cost of installing 1 HP at Niagara $28 in dynamos + turbines, the maximum economy is reached at 17% drop delivering 3000 amperes at 4980 volts at motor terminal in Buffalo.

On the Niagara Estimates contd :-

Required to deliver 20,000 HP nett in Buffalo, on the premises of the consumer, the efficiency of the motors being 85%, the drop in the motor mains 5%, the efficiency of the double conversion in Buffalo central station 85.5%, the drop in the main line 15%, and the efficiency of the generating dynamo 93%. Also as regards light the drop in the feeders mains to be 12%, (8% in feeders 4% in mains).

Nett efficiency $0.93 \times 0.85 \times 0.855 \times 0.95 \times 0.85 = \cancel{0.482}\ 0.546$ say 0.55

so that for 20,000 HP delivered at the motor belt 18200 must be generated and the Nett efficiency for the lamps $0.93 \times 0.85 \times 0.855 \times 0.88 = 0.595$ say 0.6

so that for 10,000 HP delivered as light 16700 must be generated.

Total 35,000 generated HP at the dynamo shafts in Niagara.

or 32,500 HP (24,200 kwts) at machine terminals. =

(20,650 -)	. High Motor	-	Buffalo	
(17,650 -)	. Dynamo	-		(motor 9,290, lamp 5360)
(8,860 -)	. Motor Consumer	-	-	
10,620 HP (7,500 -)	. - belts	-	-	7400
10,000 HP (7,400 -)	. Lamps	-	-	

To deliver 20,650 kwts at Buffalo at 20 miles distance including ground returns and at 6000 volts generating pressure at M.T.

The c.millage is $\dfrac{20.650 \times 1.056 \times 10^{13}}{36 \times 10^{6} \times 15 \times 85} = \dfrac{2.065 \times 1.056 \times 10^{17}}{3.6 \times 1.5 \times 0.85 \times 10^{10}} = \dfrac{2.181}{4.59}$

$= 4.75$ million cmils

$= 4.75 \times 10^{6} \times 1.056 \times 10^{5} \times 3.015 \times 10^{-4} \times 2.24 \times 10^{3} \times 6.346 \times 10^{-3}$

$= 675$ tons @ 19 cent per lb ($425.00 per ton) = $287,400 copper.

this is if overhead wire used.

If cables be employed, the distance will be increased to 22 miles by the canal or river route via Tonawanda, and this will bring the Cmillage up to

$\dfrac{2.065 \times 10^{17} \times 1.162 \times 10^{5} \times 10^{7}}{36 \times 1.5 \times 0.85 \times 10^{10}} = \dfrac{2.40}{4.59} = 5.23$ million $= (5.5$ stranded$)$

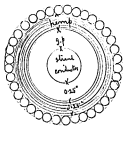
Each cable would have a strand 0.5" diam = 250,000 cmils so that there would be 22 cables in all, and there would be 14 spare cables so that in all there would be 6.5 million cmils $= 6.5 \times 10^{6} \times 1.162 \times 10^{5} \times 1.346 \times 10^{-3} = 1020$ tons $= \$432,700$ in copper. There would be 3/8" thickness of g.p. on each cable = diameter of core 1.25" + the area of g.p. $= \pi\{(0.625)^2 - (0.25)^2\}$

$\pi(0.391 - 0.063) = \pi(0.328) = 1.03$ sq. in. say 1 sq. in.

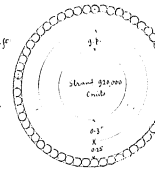
1346 feet would weigh 61 lbs or 0.045 lbs. per foot and there would be $1.162 \times 22 \times 10^{6}$ feet $= 109 \times 10^{6}$ lbs $= 109.00 \times 10^{3} = 48.7$ say 500 tons g.p.

This makes rather too thick a coating. If ½" covering be adopted as shown in the figure, then the g.p. would be in area $\pi(0.187) = 0.586$ sq. in say 0.6 sq. in. and the total weight would be 300 tons. The hemp would be ½" thick and there would be 37 # 11 B&S wires weighing each, weighing 210 lbs per mile = 225 lbs per knot mile = 49.50 lbs per cable = 108,900 lbs in all = 48.6 say 50 tons iron wire

$\pi(0.75^2 - 0.5^2) = \pi(0.563 - 0.25) = \pi(0.313) = 0.98$ sq. in. = 1146 feet per cubic foot of 40 lbs = 0.278 lbs. per foot $= 7.1 \times 10^{6}$ lbs = 3200 tons hemp

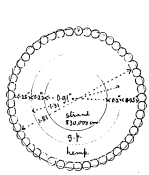


	cmils	lbs per ft	Total wt tons	cost per ton	Total cost
copper	920,000	2.5	1150	@ $425.50	$490,000
g.p.	1,500,000	0.71	300	$4480	1,344,000
hemp	1,850,000	0.64	166	$560	93,000
iron	800,000	2.4	1000	$112	112,000
					2,039,000



8500 volts P.D. at Niagara M.T. { 60,000 ℔ at motor bills Buffalo
10,000 ℔ in lamp at

	cmils	lbs. per ft	Tied to off.	Total lbs	per ton	Cost Total
copper	830,000	2.50	420,000	470	$425.50	200,000
g.p.	890,000	6.36	"	60	$4500	270,000
hemp	1,560,000	0.334	"	64	$560	36,000
iron	720,000	2.9	"	375	$112	42,000
						$548,000



With the formula $C = \sqrt{\dfrac{\pi^2 K d^3}{0.48 R \log_e \frac{D}{d}}}$

$d = 2.31$ $\quad \log_e \frac{D}{d} = 0.365$
$D = 3.33$
$R = 1.7 \times 10^{-6}$
$K = 4.9 \times 10^{-3}$

$$\sqrt{\frac{10 \times 4.9 \times 10^{-3} \times 2.31 \times 2.31}{4.8 \times 10^{-11} \times 1.7 \times 10^{-6} \times 0.365}} = \sqrt{\frac{2.56 \times 10^{7}}{2.98 \times 10^{1}}} = 10^{3}\sqrt{0.859} = 930 \text{ amperes.}$$

0.91" diam. = 0.650 sq. in.
0.650 × 6.625 = 4.20 sq. millimetre.
0.2" = 5.08 mm.

If on the other hand the cables could be stranded up to a million cmil say) 920,000 each then six cables would serve and eight might be laid making a total of 7.36 million cmil 0.3" g.p. 0.25" hemp + 56 # 11 B.W.G wires outside 0.12" diam.

The area of g.p would be approximately π ~~(0.3² − 0.5²) = π × 0.34 sq. in.~~ $\pi(0.8^2 - 0.5^2) = \pi(0.64 - 0.25) = \pi(0.39) = 1.195$ sq. in.: say 1.2 making 0.71 lbs per foot and there are $8.0 \times 1.162 \times 10^5 = 9.3 \times 10^5$ feet $= 6.6 \times 10^5$ lbs $= 6600 \times 10^2$ lbs. = 295 say 300 tons g.p. for there are $1.5 \times 8 = 12$ million cmil of g.p. in all paths per foot = 2 million of copper in weight or 5 times the weight of copper.

The hemp would be in area $\pi(1.05^2 - 0.8^2) = \pi(1.103 - 0.64)$ $= 0.463\pi = 1.455$ sq. in. $= 1{,}853{,}000$ cir. mils. or in all 14.82 million cmil $= 1.05$ mm cmils. of copper roughly) $= \frac{1}{5}$th weight of copper = 200 tons.

or more accurately) 17.46 cubic in. per foot = 0.64 lbs. $= 37.2 \times 10^{4}$ lbs = 166 tons

There are 56 # 11 wire each weighing 225 lbs per mile $= 2.39$ lbs per foot $= 2.39 \times 9.3 \times 10^5 = 22.2 \times 10^5 = 2220{,}000$ lbs = 1000 tons

+ the copper $7.36 \times 3.015 \times 1.162 \times 10^5 \div 2240 \times 425.50$ =

If the e.m.f at the Niagara generating terminals be 8500 volts then the circular mileage at 20 miles distance all included

$$= \frac{10^{9} \times 20650 \times 1.056 \times 10^{5}}{8.5^{2} \times 10^{6} \times 15 \times 85} = \frac{2.065 \times 1.056 \times 10^{17}}{7.225 \times 1.5 \times 0.85 \times 10^{6}} = \frac{2.18 \times 10^{17}}{0.921 \times 10^{6}}$$

$= 2.37$ million cir. mile $= 320$ tons. and allowing 33⅓% for spiral cable + 1.56 tons + 5% for stranding = 4.50 tons = 4 cables of 0.79 + 0.4 = 830,000 c.mils strand = 0.91" diam. The e.m.f at the high motor terminal will be $0.85 \times 8500 = 7230$ and the current will be 2856 amperes in all divided among 3 cables will be 952 amperes each.

The g.p will be in area $\frac{\pi}{4}(1.31^2 - 0.91^2) = 0.7854(1.716 - 0.828)$ $= 0.7854(0.888) = 0.698$ sq. in. per foot 8.34 cubic in. + 1 c.i. weight $\frac{64}{172.8} = 0.0369$ lbs. ∴ wt. per foot = 0.297 lbs. and the total weight $= 4.224 \times 10^5 \times 0.3 = 12672 \times 10^5 = 12672$ lbs = 56.6 tons say 60

The hemp will be approximately $\frac{\pi}{4}(1.91^2 - 1.31^2) = 0.785(3.276 - 1.716)$ $= 0.785(1.56) = 1.225$ sq. in and 1 foot = 14.7 cubic in. and each c.in weighs $\frac{20}{172.8} = 0.0232$ lbs. so that 1 foot weighs 0.34 lbs or in all 143800 lbs = 64 tons.

There will be ~~56~~ 56 # 11 B.W.G wires each 14,400 cmil = 722,000 1 cubic in. of iron weighs $\frac{480}{172.8} = 0.2778$ lbs. per linear foot = 3,336 = 2.62 lbs per foot million cmil

---

The temperature of the canal water must be in summer no higher than 70°F = 21°C. and the temperature of the g.p. in the interior must never rise above 90°F = 32°C. so that 10°C will be the max. temp elevation permissible

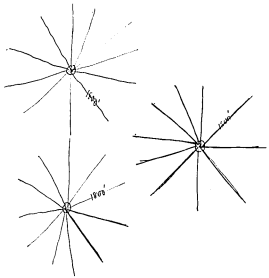
$$C = \sqrt{\left\{\frac{\pi^2 K d^3}{0.48 R} t \times \frac{D}{10 + 3D \log_e \frac{D}{d}}\right\}}$$

$K = 4.8 \times 10^{-3}$
$d = 0.91" = 2.31$ $\quad \frac{D}{d} = 1.4441$ $\quad \log_e \frac{D}{d} = 0.365$
$D = 1.31" = 3.33$
$R = 1.7 \times 10^{-6}$

$$\sqrt{\frac{10 \times 4.8 \times 10^{-3} \times 2.31 \times 2.31 \times 10 \times 3 \times 3.33}{0.48 \times 1.7 \times 10^{-6} \times (10 + 3 \cdot 1.05)}} = \sqrt{\frac{2.56 \times 10^{6}}{1.1114}} = 10^{3}\sqrt{\frac{25.6}{1.1114}} = 10^{3}\sqrt{23.0}$$

$= 480$ amperes

Feeder system.



On the amount of money necessary to invest in copper for 150,000 lamps in Buffalo at a mean distance of 1800 feet from the generating stations. Each lamp to absorb 50 Watts 8% drop in feeders 4% in mains + the neutral to be as large as the outside. No account taken of all the lie mains. The calculation deals practically with feeders 1800 feet long.

The total energy to be delivered is 7500 kilowatts at 8% drop ∴ circular millage

$$= \frac{7.5 \times 10^3 \times 3.6 \times 10^3 \times 10^3}{2.40 \times 2.40 \times 10^6 \times 8 \times 92}$$

$$= \frac{27 \times 10^{18}}{4.24 \times 10^7} = 63.7 \text{ million.}$$

Wt $= 63.7 \times 3600 \times 0.1346 = 309.0$ tons

+20% for neutral $= 370.0$ tons.

$$= \frac{1.346 \times 7.5 \times 10^3 \times 3.6 \times 10^3 \times 3.6 \times 10^3}{2.40 \times 10^2 \times 2.40 \times 10^6 \times 0.8 \times 10^1 \times 0.92 \times 10^2} = \frac{131 \times 10^9}{4.24 \times 10^7}$$

$= 309$ tons $\quad$ 370 tons

@ \$425.50 = \$157,500

On the amount of money necessary to invest in copper for 3330 HP (2500 kwt) at a distance of 4300 feet. (8600 h.p.) at 4% drop and 800 volts M.T. to be distributed at this mean distance in Buffalo

The circular millage

$$= \frac{2.5 \times 10^3 \times 8.6 \times 10^3 \times 10^3}{8.0 \times 8.0 \times 10^6 \times 4 \times 96}$$

$$= \frac{21.5 \times 10^{18}}{2.46 \times 10^6} = \frac{21.5 \times 10^{12}}{2.46 \times 10^4} = 8.74 \text{ millions}$$

The weight is $= 8.74 \times 3.015 \times 8600/2240$

$$= \frac{226700}{2240} = 101 \text{ tons @ } 425.50$$

\$43,000

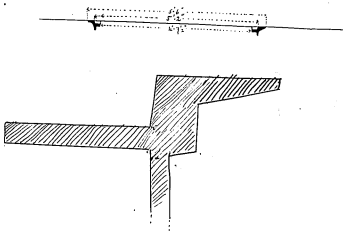
$$= \frac{1.346 \times 2.5 \times 10^3 \times 8.6 \times 8.6 \times 10^3}{8.0 \times 8.0 \times 10^6 \times 4 \times 96} = \frac{249 \times 10^9}{2.46 \times 10^4}$$

$$= \frac{2.49 \times 10^{18}}{2.46 \times 10^4} = 101 \text{ tons} = \$43,000$$

Cablegram sent 1 XI. 19 To Siemens Bros London from Robson N.Y.
"Probable approximate price of one hundred knots lightly armoured cables with stranded core four hundred and twenty square millimeter and gutta-percha five millimetre thick in several layers with intermediate compound."
Reply received 5 XI 19 To Robson Orange from Siemens
£ 1750 per knot exclusive packing delivered works Woolwich.

The water distance to City Hall is 22 statute miles
4 cable are 88 " $\times 0.876 = 77.1$ knot
£1750 @ 4.90 = \$8576 $= \$661,000$. for \$22,000

Cross section of track



Full sized rough cross section of rail on Orange road, upper part only. Each rail 30 feet in length.

Characteristic Curve of 200 volt Dynamo Machine.

27th October 1889.

Ran the 200 volt machine light without load & measured the voltage at its terminals by potentiometer while observed current strengths passed through the fields.

No. of Obs.	Speed of armature per min.	Observed reading of Jaeger ammeter in cross shunt	Corresponding current in amperes	Res. on Galv. ch.	Total res. between terminal	Ratio	Voltages
1	1495	0·145	0·113	345	9850	28·56	40·87
2		1·00	0·202	200	9730	48·75	69·8
3		1·45	0·270	172	9975	58·01	83·0
4		1·35	0·254	170	9873	58·10	83·2
5		1·90	0·288	142	9943	70·04	100·2
6		2·45	0·320	127	9930	78·18	111·8
7		3·02	0·370	112	9913	88·52	126·7
8		3·45	0·394	103	9913	96·26	137·7
9		3·85	0·445	97	9997	103·0	147·4
10		4·35	0·475	90	9991	111·0	158·9
11		4·68	0·496	87	9987	114·8	164·3
12		4·52	0·480	89	9990	112·2	160·5
13		4·95	0·525	82	9983	121·8	174·3
14		5·48	0·556	78	9979	128·0	183·2
15		6·08	0·622	74	9975	134·8	192·9
16		6·51	0·667	70	9970	142·4	203·8
17		7·12	0·718	66	9966	151·0	216·1
18		7·60	0·814	63	9963	158·1	226·3
19		7·98	0·885	61	9971	163·5	234·0
20	1500	8·30	0·950	59	9959	168·8	241·6

Measurements of resistance on Orange Track. of the Cross Town Rail Road

A 0 1 2 3 4 5 6 7

B

Line A	from	0 to 1	on the same metal		0·01 ω	Hyppion Distance	15 feet
B					0·01 ω		
A		0 - 2	across 3 junction		0·44 ω	roughly	60
B					0·84 ω		
A		0 - 3		5	0·84 ω		108
B					1·24 ω		
A		0 - 4		7	0·94		192
B					0·24		
A		0 - 5		9	1·09		261
B					1·34		
A		0 - 6		11	1·14		318
B		6			1·14		
A		0 - 7		15	1·34		411
B					1·44		

Average resistance of each junction about 0·1 ω and variable.
Res. at 0 from Track to Rail 19 ω roughly and with a car on the same pair of metals 14 ω

Design for a four pole continuous current transformer

The bar motor is intended to deliver 10 HP. to its axle, if the efficiency of the motor be 85% then the HP. delivered to the motor will be 11.75. also if the drop in the line be 15% then the HP. at machine terminals will be 13.8: and if the drop in the armature be 5% the HP. absorbed by the machine secondary will be 14.6. If 2.5 HP. be consumed in keeping the machine up to speed in foucault currents, friction, and magnetism, then the power delivered to the transformer will be 17.1 HP in the primary ct. with 18 HP. at m.t. in the engine room 10 HP shall be realized at the car axle.

The transformer will receive its pressure at m.t. and will deliver it pressure at m.t. 20 volts.

13.8 HP = 10,300 Watts so that the current will be 515 amperes. The diameter of the armature ring to be 24" externally and 7" broad. The peripheral speed to be 5000 feet per min. The res: of the machine to allow 1 volt drop at full load = 0.00195 ω and the resistance of each quadrant must not exceed 0.000488 ω. Allowing an average field of 8 gauss the peripheral velocity 2500 cms per sec: the effective length of each turn 2.3 cms, then if x be the no: of turns in the quadrant

$$x = \frac{21 \times 10^8}{8.0 \times 10^4 \times 2.3 \times 10^1 \times 2.5 \times 10^3} = \frac{21 \times 10^8}{4.6 \times 10^7} = 45.7$$

keeping 45 turns per quadrant or 180 turns for the whole ring the res: per turn of the coarse wire ct: is to be 0.000001 or 10 microhms. If the length be 25 cms then the res: per cm must be 0.4 microhm and copper @ 55° has a resistivity of 2 microhms so that there must be 5 sq: cms: of cross section. Allowing 10% for insulating space 5.5 sq: cms. The diameter of the exterior section center being 24.5" = 62.2 cms = 195.5 cms. periphery = 1.09 cms per turn so that the winding would have to be 5 cms. deep. to obtain the required result.

Keeping 20 bars in the commutator, the only reduction possible from 180 turns in the circumference is to 20 turns in the circumference = 22.5 per quadrant. The field necessary for this must average

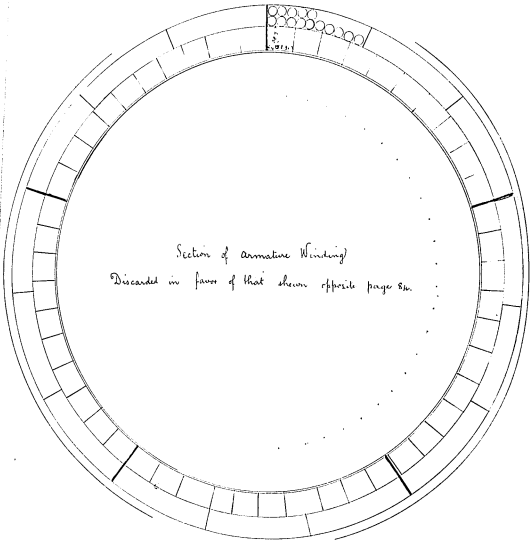
$$\frac{21 \times 10^8}{2.25 \times 10^1 \times 3.0 \times 10^1 \times 2.5 \times 10^3} = \frac{21 \times 10^8}{16.88 \times 10^5} = 1244$$

which must therefore be provided for.

This being allowed the res: of the single turn reduces to 20 microhms and the res: per cm: $\frac{20}{30}$ = 0.67 microhm the cross section to 3 sq: cms: with 10% allowance 3.3 and the linear space on the periphery being 2.18 allows 1.38 cms thickness of bar. But sufficiently increasing the cross section within the armature the thickness on the outside can probably be proportionately diminished to the proper amount.

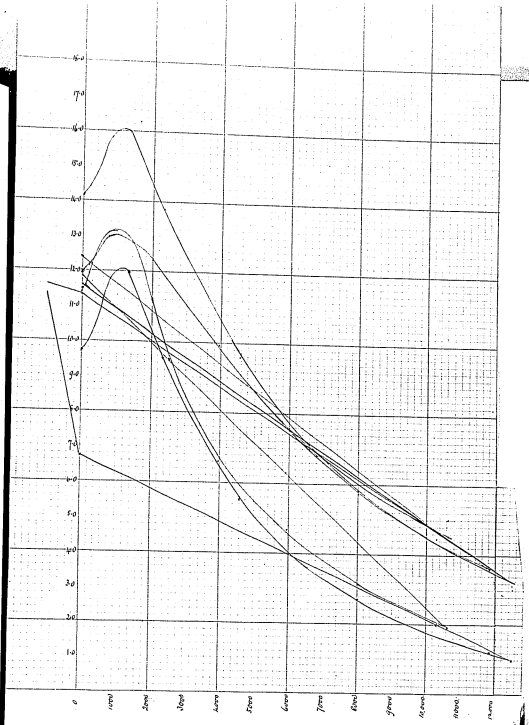
The field wire ct: must generate 1050 volt, it will therefore have 50 turns as many turns as the coarse wire ct: there will thus be ~~150~~ 90 × 50 = 4500 turns in all or 1125 turns per quadrant. or 25 turns per commutator bar (of 180 in the circle). 17.1 HP = 12,760 Watts at 1050 volt = 12.15 amperes in primary ct: at full load. That will be 3.04 amperes in each quadrant and allowing 400 c.m. per ampere = 12.16 c.mm = #20 B&S. 0.035" bare or 0.040" covered. Allowing 18" (1.5 ft) per turn the length of wire on each quadrant will be 1690 = 141.25 ω and the res: of the whole machine 3.58 ω say 4.0 ω hot.

The diameter of the iron wire armature being 24" then covered with four thickness of oilpaper 24 × 0.0045 = 0.09 = 24.09" and the circumference 75.53". The internal diameter of the ring will be 20" and



Section of Armature Winding

Discarded in favor of that shown opposite page 8/m.



over the oil paper 19.95. circumference 62.68". this divided into 180 bars gives 0.3148" for commutator segment. Six turns will fit into this space and four deep will make a thickness of winding = 0.200". The diameter of the fine wire surface will thus be 24.44" and 19.55" respectively.

Calculations for a 2-pole transformer.

A #3 Edison machine has an output of 7.5 kilowatts
" #4 " " " " 10 " "
13.8 P = 10,280 Watts. By boring out the fields a little more and decreasing the speed and magnetism, the difference may be made up.

The diam. of the armature is 6.25" the length of 12" over the armature proper + 0.02" all over for 4 thicknesses of paper.

The fine wire commutator will be a regular M. vol. of 100 bars. The coarse wire commutator will be of regular No 20. of 50 bars. The E.M.F to be generated in the fine wire ct. = 1050 v.
" " " " " " coarse " " = 21 v.

A no 4 machine making 1600 revolutions per minute generates 125 volts. It has 1 no 9. B.W.G. wire twice around over 50 dis or 100 complete turns = 100 half turns on each side of the armature. Consequently the volts per wire are 1.25 at 1600 revs. if a trial speed of 2000 revs. be allowed, the volts per wire would be 1.563, and to generate 1050 volts 672 turns would be required or about 14 turns to each division if the magnetism were maintained.

The air space in a #4 is $\frac{7.25 - 6.25}{2}$ = 0.5" on a side. As a trial value the boring can be increased 0.25" in rad: giving 0.75" on a side. The c. millage of a #9 wire is 21,900 which for 80 ampere gives 275 X2 = 550 c. mil. per ampere. Allowing 450 c. mil for 12 ampere (full load) = 5400 c. mils for 2 wire = 2700 c. mils for one wire = 0.052". The nearest wire to this is #16 B.&S (0.0508" 2590 cmils = 430 cm per amp.) Allowing 0.016" for covering = 0.065". The magnetic field will be reduced for the same exciting power in the ratio of 3 to 2 or to 1.06 volts per turn at 2000 revolutions, but by adding 50% to the weight of copper (63 lb ratio) the original magnetic field where no iron is left in ct. may be expected in which case 15 wires per div = 750 turns round will be needed.

The clearance will be ⅛" all round = 0.125". The armature diameter is thus 7.5" over the wire. The armature body insulated is 6.3" in diam. leaving 0.6" for winding space. The total area of winding space is thus 0.785 (7.5² − 6.3²) = 0.785 × 16.56 = 13.0 sq. in. There will be 50 divs each 0.050" thick and 0.6" long = 1.50 sq. in. There will also be 3 thicknesses of paper in the coil = 0.015" and 22" around = 0.33 sq. in. ∴ 13.0 − 1.83 leaves 11.17 sq. in. of useful winding area. This halved leaves 5.58 sq. in. and 750 turns mean 1500 wire sections 0.0072 sq. in = 0.0108 less 0.015" = 0.0146"

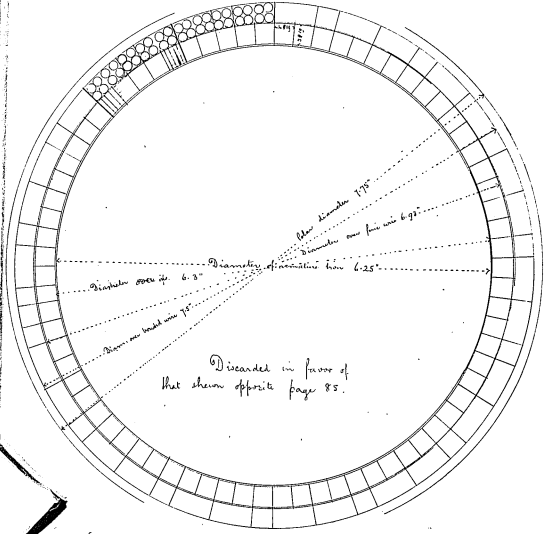
For the coarse wire ct. we have 5.58 sq. in: area and 30 conductor sections in this amount = 0.186" = (0.431)²

The circumference of the armature over the bare insulation 6.3π = 19.79" and 50 divs of fibre + paper 0.05 = 2.5" leaving 17.29" at base for winding #19 wire = 0.042 + 0.014 = 0.056" 309 turns round say 300 and 5 layers make up the 1500. There 5 layers = 0.28" + 7 thicknesses of paper 0.025 = 0.305" so that the diam over this wire = 6.93"

The circumference over the insulated fine wire = 6.93π = 21.77" allowing 5 divs each 0.05" = 0.25" leaves 21.52" bare circumference. The depth available being 0.285" = 2 wire 0.142" covered. 150 such wire = 21.3" so that each block is supplied by 20 wire #8 B&S (0.128") in 2 layers of 10 each or 150 turns round 300 half turns

Section of 10 kilowatt transformer armature.

#4 machine with poles bored out to 7.75" diam:
1050 volt fine wire c.m.f @ 2000 revs: or under
21 " coarse " " "
50 = conversion constant.
75 bars in fine wire commutator
15 " " coarse " "



(1) Discarded in favor of that shown opposite page 85.

Winding

Fine wire laged on first in 75 slots.
One #19 B.W.G 0.043" covers to 0.05". 10 turns round
Making in all 750 commutators in 5 layers 6 turns to the division
Coarser wire laged on outside in 15 slots.
Two #5 B+S wire 0.123" covers to 0.148" once round.
Making in all 150 commutators in 2 layers of ten per main slot.
About 4800 feet of #19 B.W.G wire weighing about 28 lbs. = 3530 c.m.s in all
" 500 " " #8 B+S " " 25 " = 329,000 " " "

The c.millage of #8 B+S is 16,380 and there are 10 wires in parallel = 163,800 and two such sets one on each side of the armature = 327,600 c.mils in all. Each such composite wire makes 75 turns round the drum, and each such turn is about 3·3 feet. so that the composite conductor is 24·75 feet in length. The res: of the armature is thus about $\frac{24.75 \times 11}{327,600} = \frac{292.25}{327,600} = 0.000892$ say 0·0009 ω and at 500 amperes the drop will be 0·45 volts. while the energy absorbed at full load will be $0.25 \times 10^4 \times 9 \times 10^{-4} = 2.25 \times 10^2 = 225$ Watts.

The c.millage of #19 B.W.G. wire is 1764 and the two sides of the armature give 3527 there will be 750 turns @ 3·2 feet = 2400 feet. the res: will thus be $\frac{2.400 \times 10^3 \times 11}{3.53 \times 10^3} = \frac{28.4}{3.53} = 8.05$ ω. hot, the drop at full load 98 volts and the energy absorbed 1200 Watts. (on the amp for the shunt)

This arrangement favors the coarse wire circuit at the expense of the fine.

Suppose 96 commutator bars in the fine wire commutator and 16 bars in that of the coarse wire.

The circumference over insulation wire = 19.79" and with one paper between each block and one fiber division at every third block = 96 × 0·0090" = 0·86" + 32 × 0·045" = 1.44 total 2·30" leaving 17·49" 17.49 ÷ 288 = 0·0607 − 0·014 = 0·0467 and #17 B+S = 0·0453 so that there will be this wire 3 times round per div: or 8640 turns in all the c. mils = 2050 or 2 in parallel 4100 ÷ 12 = 342 c.mils per amp. There will be 3 layers = 0·180" + 0·01 = 0·190 × 2 = 0·38 + 6·3 = 7·06" over insulated fine wire set. The circumference = 22·18". has 16 divisions of fiber @ 0·050 = 0·8" leave 21·38" ÷ 20·4 = 0·1048 − 0·014 = 0·091 and there will be two such layers = 0·182 × 2 = 0·364 = 7·42". Fourteen of these wire will be in parallel and each has 8230 c.mils or 115,200 c.mils in all + 2 such sets give 230,400 c.mils. 86 turns @ 3·3 feet per turn = 284 feet so that the res: of the coarse wire set hot will be $\frac{284 \times 11}{230,400} = \frac{286}{230,400} = 0.00124$ and

There will be 864 turns of 3·2 feet in the fine wire set = 2700 feet the c.mils 2050 of #17 B+S (0·0453") or 2 = 4100 so that the res: will be. $\frac{2700 \times 11}{4100}$, $\frac{297.00}{4100} = 7.24$ ω hot and the drop at full load c 87 volts while the drop in the coarse wire is 0.62 volts. = 3%
" " " fine wire is ·87 " = 7·6%
Total efficiency taking out magnet friction 89·3%

---

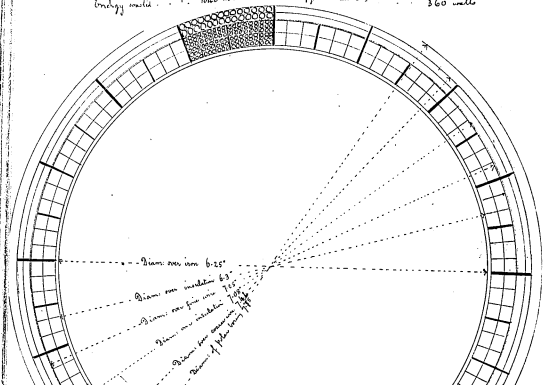
1 sq. cm of iron has a res: of 9.6 microhms @ 0°C and at 20°C 10.6 microhms 1 sq. in = 6.45 sq. cms. = $\frac{10.6}{6.45}$ = 1.64 microhms and 1 foot = 50·1 microhms so that 300 feet of distance = $\frac{600}{6.45}$ feet of rail = 30,000 microhms = 0·003 ω for one square inch of metal = 0·0015 ω for two inches = 0·001 ω for three

and with 500 amperes the drop would be 5 volts or if on full load at that distance the next transformer took half load then 250 amperes would give 2·5 volts drop = 19·8 − 2·8 = 17·3 volts at machine terminals.

The distance from the Engine Room to the Connecting point on the roads will be 2400 feet. The current supplied to one idle transformer will be 2·5 amperes, suppose and to 2 active ones 12 amperes each = 26·5 amperes. The p.d. at transformer terminals is to 1050 and at 50 volts drop = 1·89 ω 4800 feet = 0·000393 ω per ft. = #8 wire.

Cross Section of Continuous Current Transformer Armature (Full Size) for 10 Kwts.

Fine wire commutator 96 blocks about 20 volts per bar
Coarse - 16 . . 2.6 . . .
Speed reckoned at 1730 revs: per min.
Winding: Fine wire beneath 1 wire (#17 B.&S) = 0.0453" = 2050 c.mils (340 per amp/ft)
9 turns round = 864 turns in all.
Coarse wire above 14 wires (#11 B.&S) = 0.091" = 115,200 c.mils (1,160 per amp/ft)
over round = 16 turns round in all.
Coefficient of conversion 4.8.
Res: of primary 7.25 = Ret. Res: of secondary 0.0012 = Ret.
Drop in . @ f.l. 87 volts Drop in . @ f.l. 0.62 volts
Energy wasted . 1080 watts Energy wasted . . 360 watts



2700 feet of #17 B&S = @ 0.0062 lbs per ft. 16.2 lbs.
750 " #11 B&S = @ 0.024 - . 18 lbs
60 lbs on each limit of #11 B.W.G magnet wire = 120 lbs in all.

Leakage between Low Volt Mains

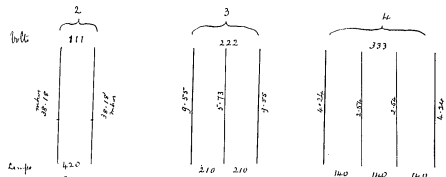
1st November. Two 24 foot iron rails (in ordinary) surface conditions were buried so as to be covered by about one inch of soil. They were placed in the courtyard, parallel to each other and 3 feet apart. They capers about.
The day preceding had been wet and the ground was damp but to make more certain of the thorough wetting, about 12 pails of water from the tap were thrown on the soil above and between them. By bridge w/ the minimum res: was about 100 - making the leakage 0.2 ampere. By upright ammetre, rather insensitive the leakage was 0.55 on m.m. scale = 0.13 ampere. By the Siemens small tangent galv: the deflection was 51° with each direction of current and tan 51° = 1.235 = 0.16 ampere. Taking the highest 0.2 ampere for 24 feet = 0.8 ampere per 100 feet = 8 amperes per 1000 feet and for 2750 = 22 ampere. By painting the rails with heavy coating of pitch, even this loss 22 × 20 = 440 Watts or 0.75 HP at station may be reduced indefinitely.

4th November. Magnetic Experiment for 3 wire system

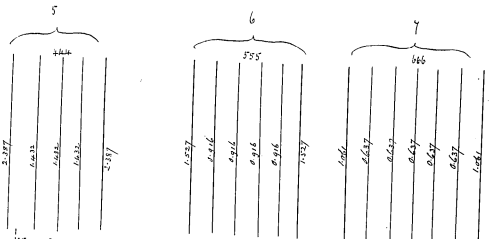
Tried the effect of short-circuiting one lamp out of the two represented in the diagram. The result was to bring 200 volts pressure on one limit and one lamp. This had resulted in every case in burning the lamp finally although the voltage would fall to 100 in about ten seconds.

The bore of the #10 fields has been increased from ~~7.25~~ 7.25" to 7.75" an increase of 0.25" radius. The entrefer previously was 0.5" and it is now 0.75". The reluctance of the air space has diminished the flux to 0.67 of its previous value and the leakage will bring it down to say 0.6. Consequently to restore the field its magnetic motive force should be increased 1.67 times. The reluctance of one limit of the magnet is 18.7 of #17 B.W.G. = 14340 feet and the diameter of the core is 7.4" so that the circum: = 1.94 feet = 2240 turns. or on both limits together 4480. The current at full load = $\frac{125}{56}$ = 2.23 so that the amptire turns are 9000 and 15,000 turns to be provided for.
The surface = 32 × 12 = 384 sq. in. = 2480 sq. cms = 100 Watts @ 25 sq. cms per Watt. = 200 Watts in all. @ 20 volts = 10 amperes = 1500 turns for 2 w. The length of each turn being 2 ft. length = 700 on each limit = 1500 feet per w = #11 wire diam: 0.120" = 0.120" end: the length begins 12" = 90 turns = 5 layers. = 1" dep. + the weight 121 lbs.
If #10 were used then would be 0.144" diam: covered .80 turns to the layers and 10 layers = 1 w on each + the total weight 189.

Neutrals 60% wt of outsides.



	2	3	4
Lamps	420	210 210	140 140 140
Amps	210	105	70
volts	100	200	300
Miles	76.46	24.83	13.56
ft	100	32.5	17.8
Saving		67.5	82.2
Saving on feeding		47.5	45.4
Distances attainable in terms of 2 wire		1.76	2.37
Area		3.09	5.62
Voltage of lamp which on 3 wire system would have equal economy		100	134.7



	5	6	7
Lamps	105 105 105 105	70 70 70 70 70	60 60 60 60 60
Amps	52.5	35.5	30
volts	200	500	600
Miles	9.07	6.78	5.07
ft of copper	11.0	8.8	6.14
Saving	88.1	91.2	93.86
Saving on feeding	33.1	26	21
ft . . . 2 com	82.1		
Dist. attainable on 3 wire	2.90		
. . . 3 .	1.44		
Area . . 2 .	8.4		
. . . 3 .	2.1		
Voltage of lamp — Economy	165		

Investigation of Copper Economy in 3 wire and multiple wire systems.

In the Brooklyn system of 3 wire mains and feeders, the lamps were 19,250 of 115 volts and 0·5 ampere, and with 10% drop in feeders and 17% in mains the feeders were 35,800 feet in total length embodied 15,250 million milfeet of copper and cost $69,000, while the mains were 60,800 feet embodied 8,040 million mil feet of copper and cost $56,400 each.

The cost of copper is related to the total cost of underground wiring in the following manner. (all material included) copper @ 19·2 per lb (mid-

Feeders

No.	Edison #	G.M.	G.M. Mult.	Weight copper per ft lbs	Manufacture cost of tubes per ft $	Relative cost of tube to that of conductor	No.	Edison #	G.M.	G.M. Mult.	Weight of copper per ft lbs	Manufacture cost of tubes per ft $	Relative cost of tube to copper
1	650	650,000	200,000	4·52	1·61	1·87	1	500	500,000	500,000	4·52	1·52	1·78
2	600	600,000	200,000	4·22	1·54	1·92	2	450	450,000	450,000	4·07	1·43	1·95
3	550	550,000	200,000	3·92	1·48	1·99	3	400	400,000	400,000	3·62	1·34	2·01
4	500	500,000	200,000	3·62	1·39	2·02	4	350	350,000	350,000	3·17	1·24	2·06
5	450	450,000	150,000	3·17	1·30	2·16	5	300	300,000	300,000	2·72	0·98	1·90
6	400	400,000	150,000	2·87	1·24	2·28	6	250	250,000	250,000	2·26	0·88	2·05
7	350	350,000	150,000	2·56	1·15	2·36	7	200	200,000	200,000	1·81	0·77	2·24
8	300	300,000	100,000	2·11	0·91	2·27	8	150	150,000	150,000	1·36	0·67	2·59
9	250	250,000	80,000	1·75	0·83	2·49	9	120	120,000	120,000	1·09	0·53	2·56
10							10	100	100,000	100,000	0·90	0·50	2·92
11							11	80	80,000	80,000	0·72	0·46	3·36

In the Brooklyn district the manufacturing cost of the tubes for feeders was $46,000 and the copper alone $20,300 roughly) or 2·27 to 1 and the mains $37,600 and copper alone $13,800, a ratio of 2·73 to 1. A reduction in the dimensions of copper in the feeder does not reduce the price of tube in same proportion.

Since in this district the ratio of the copper in mains to that in the feeders was about 2 to 3 and the neutral is 30% in the feeders of the outsides while equal to the outsides in the mains, it follows that setting all the lamps at the centre of distribution in each circuit, the neutral has 60% of the weight of an outside.

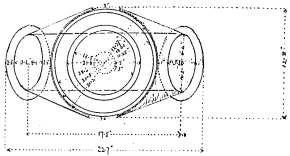
The general formula for the weight of copper in a n-wire system compared with that on the same system with 2 wire is

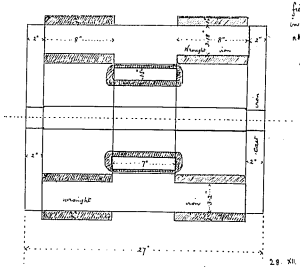
$$c = \frac{C}{(n-1)^2}(0.3n + 0.4)$$

where C is the 2 wire weight

The opposite page gives the conditions of various systems up to 7 wire for copper only. Thus the 3 wire system reaches 75% further than the 2 wire system and covers 3·1 times the area for the same weight of copper. The 5 wire system again will reach 2·9 times further than the 2 wire and 1·4 times further than the 3 wire, with areas 8·4 and 2·1 times respectively.

Car Motor 8





N.B. This elliptical field form was discarded in favor of circular sections as shown on page 60. Other particulars retained as here stated.

28. XII. 89.

Speed 1350 revs. per min
22.5 . . . .
= 1.45 m

Peripheral 4230 ft per min
2.250 cms . sec

Commutator Bars 60 =
Commutator 8 in dia

voltage Light 20
Loaded 15

amperes 75 amp + 20 in field Light
- 500 . + 15 . . loaded
Power absorbed 2 HP 1500 watts Light
" " 10 HP 7500 . loaded.

Winding Grammer ring
6 # 7 wire wire round to each division in
2 layers of 3 above and 3 of 2 below.
Res: of armature 0.0113 ω
" field coils 1ω each 2 series of 2
Arm 50 lbs # 7 B.W.G. s.c.
96 . # 13 . . . magnet.
Drop in armature full load = 0.6 volts.

On first trial with 20.5 volts on field in series and 1.1 ω on terminals Revolutions 85 per min with 3.1 . . . 288
which last fell to 220 on increasing field voltage to
This would promise 1350 rev. @ 14.5 volts terminal pd
The final history of this armature is recorded in Book III p. 137.

Alterations in the Car Motor Design.

The speed has been increased from 3000 to 4230 feet per minute or 1350 revolutions per min: The diameter on the iron being 11.25" or 11.30" over paper = 36.48" circum: $\frac{36.48}{60}$ = 0.608" width of one block. One third of this length = 0.203" or 0.188" allowing for insulation, and #7 = 0.180". Two such layers = 0.360" so that the diameter of the bore = 11.3 + 0.720 + 0.25 = 12.27" diam. The internal diam: of the ring = 8.47" and over paper 8.2" and at 0.5" inside = 7.4" . . 7.4 × 3.14 = 23.24" and this divided by 0.195 = 120 so that the winding will be 60 blocks each 6 wire in 2 layers of 3 broad above and 3 layers of 2 turns below.

The present cores are 4.5" in diam: so that their area = 6.36 sq. ins. for elliptical cores $\pi ab = \pi d^2$ and if $a = \frac{1}{2}$ then $b^2 = 2d^2$ or $b = d\sqrt{2} = 1.414 \times 4.5" = 6.36"$ and $a = 3.18"$
The length of the mean turn with 1" winding space will be

~~$\frac{\pi}{2}\left(\sqrt{3.5^2 + 6.5^2} + \sqrt{4.5^2 + 7.5^2}\right) = \pi\left(\sqrt{12.25} + \sqrt{20.25}\right) = \pi(3.5 + 4.5) = 25"$~~

$$\frac{\pi}{2}\left(\sqrt{\frac{3.2^2 + 6.4^2}{2}} + \sqrt{\frac{5.2^2 + 9.4^2}{2}}\right) = \frac{\pi}{2}\left(\sqrt{\frac{10.24 + 40.96}{2}} + \sqrt{\frac{27.04 + 70.56}{2}}\right)$$

$$= \frac{\pi}{2}\left(\sqrt{25.6} + \sqrt{48.8}\right) = \frac{\pi}{2}\left(5.05 + 6.98\right) = \frac{\pi}{2}\left(12.03\right) = 6.015\pi$$

$$= 18.9"$$

9.6 lbs of #13 B.W.G. wire 0.095" on all four cores = 24 lbs on each core @ 36.6 ft per lb : 8840 feet = 4 × 26352" ÷ 19 = 580 turns. 8 + 0.110 = 70 turns 9 layers. res: 1 ω per cut + all 4 in series = 4 ω . 18 ω give 4.5 amperes = 5040 ampere turns on each pair of limbs. = 6336 amp. Reluctance = 0.096 , flux = 1056,000

The ~~total flux~~ will be given by the ~~expression~~ equation

$$20 \times 10^8 = \phi \times 60 \times 22.5 \quad \therefore \phi = \frac{20 \times 10^8}{1.20 \times 2.25 \times 10^3} = 16 \times 10^6$$

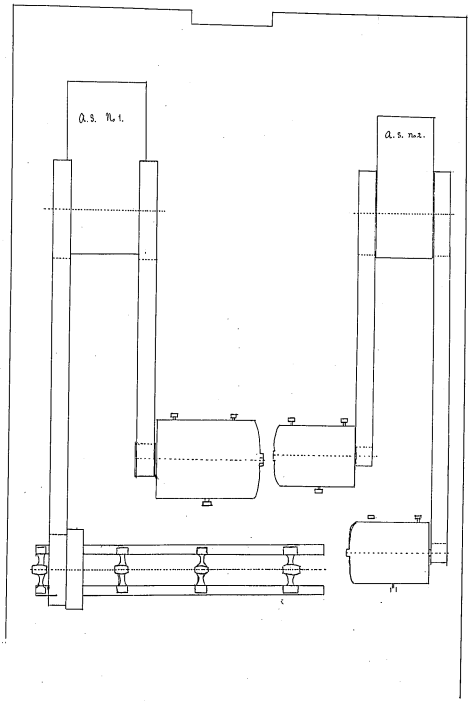
and allowing 30% for leakage gives 2,080,000 total lines.
The air spaces and winding spaces together (centres) constitute 2.5 cms and the area 750 sq. cms = $\frac{1}{300}$ = 0.0033 which with the armature rib proper may be taken as 0.006. The total number of ampere turns required is therefore $2.08 \times 10^6 \times 6 \times 10^{-3} / 1.257 = 9930 = 4965$ ampere turns on each limb. The surface of each limb is about 7" × 22" × 8" . 176 sq. ins = 1135 sq. cms. and allowing 10 watts per volt = 113.5 Watts per limb @ 7.5 volts = 15.2 amperes
13 wire 24 lbs on each limb and in two series will have 2 ω res: in each series = 15 – 20 amperes in the field altogether and 7.5 – 10 amperes in each limb = 10500 to 14,000 a.t. according to the voltage.

Res: of armature = 45 feet ÷ 12 = 3.75 feet of #7 wire = 0.0012 = length of wire = 500 feet of #7 = 50 lbs: in all.

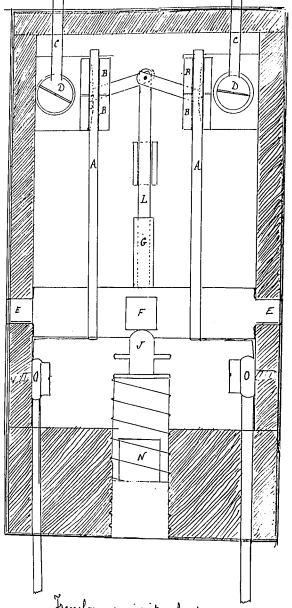
Ground Plan of Dynamo Room.

Scale $\frac{1}{40}$th actual size.

October 1889 before increasing capacity of dynamos.
No 1 engine driving the shafting + 1 #20 No 2 engine driving a pair of #10s.



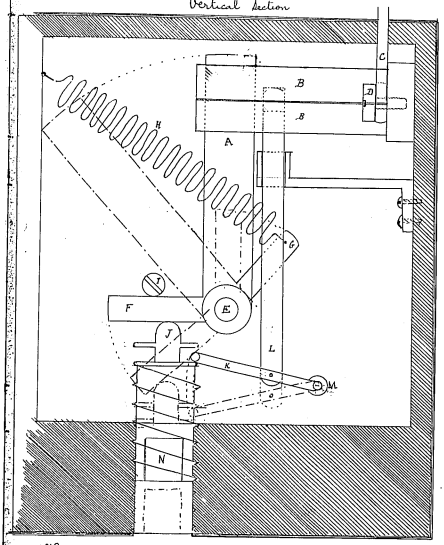
Vertical section
Parallel to axis Full size



Transformer circuit closed.

Design of an apparatus for disconnecting the transformer from the high-tension circuit by hand. Full size

Vertical section



The conducting blades A connected to the transformer are held by the double clips B.B. which are connected to the high tension circuit by the wires C under the screws D. The blades rotate in the vertical plane round the axis E and are in rigid connection with two arms F and G. The latter is pulled by the spiral spring H and the former is kept in check by the limiting stop I above and the point of the screw J beneath. This screw J is of coarse thread and of hard rubber. It carries in its motion the end of the lever K pivoted at M and bearing the vertical toggle L.

Three turns of the hard rubber screw which is rotated by a key inserted in the hollow N depress the screw J and lever K whose toggle during the last turn releases the detents on the end of B and allows the blades to fly back under the influence of the springs to the position shown in dotted lines. To close the circuit the screw is turned the opposite way forcing up the lever F until the detents close on the blades A.

The blades A are connected by straps to the washers of the screws O which communicate by wires with the transformer.

November 9th

Magnetic Experiment.

Two magnets were hastily wound as follows:-

Five plates of cast iron were selected each 20 x 20 x 1.27 (8"x8"x½") and four were superposed. Two ones were thus obtained one 5·1 cms and the other 1·27 cms thick. These ones were wound with one layer of tape. ~~The~~ Equal lengths of the same size wire (6300 cms of # 24 B.W.G silk covered 0.022" (0.056 cms) were then wound on so that the thick magnet had some 120 turns and the thin one about 140. They were then connected in series and about 3 ampères passed through them. No appreciable difference in their magnetic power could then be discovered by any rough method, such as the holding power, or the number of nails executed by a needle at a given distance, even when pole plates of the same breadth were laid on each.

Speculations on intermolecular distances and force.

1 lb. of gunpowder is stated to possess a total energy of about 500 ft lbs. Its specific gravity being about 1·8, 454 grammes occupy about 250 c.c. so that 1 c.c. has an energy of about 2 foot tons = 6.07×10^{10} ergs.

In one cubic centimetre of powder there may be some 10^{25} molecules at an average distance apart of $\frac{1}{200,000,000}$ centimetre.

Let us call this mean distance d

If we imagine all these molecules at rest and equidistant from each other the path from one to its nearest neighbor being d then it is quite possible that the atoms before explosion are maintained in somewhat unstable equilibrium at a distance from the inertia center of each molecule $< \frac{d}{2}$. Suppose we say $\frac{d}{4}$. This is the distance to which each half molecule (neglecting the chemical formula) would have to be moved after ignition in order to place the atoms beyond the range of their affinitive attractions. The force exerted in separation would probably have a steep gradient, but we may call the mean force f. Then

$$2 \times 10^{25} \times f \times \frac{1}{1,300,000,000} = 6.07 \times 10^{10}$$

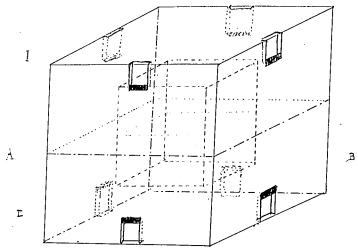
$$\therefore f = \frac{6.07 \times 10^{10} \times 1.8 \times 10^{9}}{2 \times 10^{25}}$$

$$= 5.5 \times 10^{-6} \text{ dynes}$$

$$= 5.5 \text{ microdynes.}$$

Trial of current strength necessary to properly operate a 1400 ω W.U. telegraph relay.

By means of a rheostat and the Siemens tangent (copper coil) galv: the current from 4 fuller cells was regulated till Mr Edison was satisfied with the relay operation. The res: was 350ω. $\frac{8}{350} = 0.020$ amp. The deflection 10·20° = 0.0214 so that 25 milliampères is a fair allowance, and 4 more cells for leakage say 40 at the battery end.



$\frac{r\,dr}{2\pi x}$ $\quad 2\pi \log e = \frac{2}{e}$

The heat generated in the ring is $2\pi x\,dx\,i^2\rho$ ohmwatts. The resistance beyond is $\frac{\sigma}{2\pi}\log_e\frac{A}{x}$

$$\frac{d^2v}{dx^2} = \frac{dv}{\frac{\sigma}{2\pi}\log_e\left(\frac{A}{x}\right)} = 2\pi x\,dx\,i^2\rho$$

$$\frac{dv}{dx} = i^2\rho\sigma\, x \log_e\left(\frac{A}{x}\right)$$

$$\frac{dv}{dx} = i^2\rho\sigma\, x \log_e\left(\frac{A}{x}\right) \qquad \left(x\log A - x\log x\right) \qquad \left(\log_e\left(\frac{A}{x}\right)\right)$$

$$v = i^2\rho\sigma\int x\log_e\left(\frac{A}{x}\right) \qquad x\log_e\frac{A}{x} = -\frac{A}{x}$$

$$= i^2\rho\sigma\left\{\left(\frac{x^2}{2}\log A\right) - \frac{2x^2}{2}\left(\log x - \frac{1}{2}\right)\right\} + B$$

$$= i^2\rho\sigma\left\{\log A\left(\frac{x^2}{2}\right) - \frac{A^2}{2}\log A - \frac{x^2}{2}\log x\right.$$

$$d\varphi = 2\pi x\,dx\,i^2\rho$$

$$\frac{d\varphi}{dx} = 2\pi x\,i^2\rho \qquad \varphi_1 = -\frac{2\pi x}{\sigma}\cdot\frac{dv}{dx} \qquad -\frac{dv}{dx}\,\frac{1}{\frac{\sigma}{2\pi x}}$$

$$\frac{dv}{dx} = \frac{\sigma\varphi_1}{-2\pi x}$$

$$\frac{d^2v}{dx^2} = \left(\frac{\sigma\frac{d\varphi}{dx}(+2\pi x) - 2\pi\sigma\varphi_1}{4\pi^2x^2}\right) \qquad \frac{d^2v}{dx^2} = \frac{\sigma\frac{d\varphi}{dx}}{-2\pi x} = i^2\rho\sigma$$

$$-\frac{\sigma i^2 2\pi^2x^2 + 2\pi\sigma\varphi_1}{4\pi^2x^2}$$

$$2\pi\sigma\,0$$

$$\frac{dv}{dx} = i^2\rho\sigma\, x + a$$

$$v = i^2\rho\sigma\frac{x^2}{2} + ax + b$$

When $x = X$ $\quad v = 0$ $\qquad 0 = i^2\rho\sigma X^2 \qquad b = 0$

$$v = i^2\rho\sigma\frac{x^2}{2} + ax$$

$x = X$ $\quad v = V$ $\qquad V = i^2\rho\sigma\frac{X^2}{2} + aX$

$$a = \frac{V}{X} - \frac{i^2\rho\sigma X}{2}$$

$$v = i^2\rho\sigma\frac{x^2}{2} + \frac{Vx}{X} - \frac{i^2\rho\sigma X^2}{2}$$

$$\frac{i^2\rho\sigma}{2}\left(X^2 - x^2\right) + \frac{Vx}{X}$$

$$\frac{1}{2}\frac{d\Psi}{dx} = \frac{1}{2}\frac{d\Phi}{dx}$$

$$\frac{d\Phi}{dx} = 2\frac{d\Psi}{dx}$$

$$d\psi_2 = i^2\rho\, 2\pi x\, dx \qquad d\phi_2 = i^2\rho\, 2\pi x$$

$$\phi_2 = -\frac{2\pi x}{\sigma}\frac{dt}{dx}$$

$$\therefore \frac{dt}{dx} = -\phi_2\frac{\sigma}{2\pi x}$$

$$\frac{d\Psi}{dx} = -d\psi_2\frac{\sigma}{2\pi x} + \phi_2\frac{\sigma}{2\pi x^2}$$

$$\frac{d\Psi}{dx} = -i^2\rho\sigma - \frac{2\pi x}{\sigma}\frac{dt}{dx}\frac{\sigma}{2\pi x^2}$$

$$= -i^2\rho\sigma - \frac{1}{x}\frac{dt}{dx}$$

$$\frac{d\Psi}{dx} = \frac{1}{x}\frac{dt}{dx} - i^2\rho\sigma$$

$$x\frac{d\Psi}{dx} = \frac{dt}{dx} - i^2\rho\sigma x$$

$$x\frac{d\Psi}{dx} = -i^2\rho\sigma x^2 + x$$

$$\frac{dt}{dx} = -\frac{i^2\rho\sigma x}{2} + \frac{\sigma}{x}$$

$$t = -\frac{i^2\rho\sigma x^2}{4} + \alpha\log x + b$$

If $x = X$ $\quad t = T$ $\qquad T = -\frac{i^2\rho\sigma X^2}{4} + \alpha\log X + b$

$x = 0$ $\quad t = 0$ $\qquad 0 = \alpha\log 0 + b$

$$\frac{dt}{dx} = -\frac{i^2\rho\sigma x}{2} + \frac{\sigma}{x}$$

$$t = -\frac{i^2\rho\sigma x^2}{4} + \alpha\log x$$

Experiment on the direction of electromagnetic stress in magnetized iron

November 11th. An iron box cast at the Phonograph factory in the former of an almost entire rectangular parallelopiped was prepared in two halves capable of being united by two screw lugs.

The box completed was 6.1 cms long 6.1 cms broad and 6.5 cms deep externally. In the interior it was nearly 3.8 " " 3.8 " " " 3.8 " so that the thickness of the walls were about 1.4 cm at every point. Four holes [] were cut in each half 1 cm × 0.25 cm. with external and internal grooves to assist winding.

The sides of the box were then wound with silk covered copper wire 0.016" and 0.020" over a single thickness of paper.

On side #1 the coil at right angles to the line AB had 30 turns (a)
" " 1 " " parallel " " " " 30 " (b)
" " 2 " " " " " " " 30 " (c)
" " 2 " at right angles " " " " 30 " (d)

The inductances of the two coils on side 1 were measured, first with the cube on the table, second on between the poles of the large unexcited electromagnet, and third between those poles when the magnet was excited. The faces A and B were in contact with the pole, so that the magnetic flux was ∥ to (b) and ⊥ (a). If then the magnetic strain allowed freedom of molecular motion at right angles to the stress, then the inductance of (b) should not be reduced while that of (a) would reduce owing to saturation. The actual results obtained as shewn in the following table make it evident that the reluctances were nearly equal — and allowing for the reduction of flux due to the slit perhaps quite equal — in both directions, so that if iron is magnetized in such a way that its reluctance increases in the direction of the flux it increases equally or nearly equally in other directions.

No.	Bridge	Resp. of coil, Ohms	Resp. for self balance	Inductance quadrants	Inductance Henries	Position of cube.	Coil tested		
1	1000/1	3.761	0.400	0.00150	15.02	on table	(a)		
2	"	3.740	"	0.00189	14.96	" "	(b)		
3	"	3.720	0.450	0.00168	16.89	Between pole unexcited	(b)		
4	"	3.757	0.430	0.00162	16.16		(a)		
5	"	3.758	0.030	0.00018	1.128	Between poles strong excitation abt 12 amp.	(a)		
6	"	3.726	0.077	0.00029	2.870		(b)		
7	"	3.727	0.147	0.00055	5.476	Between poles Mild excitation abt 0.5 amp.	(b)		
8	"	3.757	0.072	0.00027	2.705		(a)		
	T.B. 2430								

Tests of a certain material named Vulcabestos made for Mr Insull.

Received various samples of this insulating material on 1st November. It has a very fibrous structure, and appears to be a pressed combination of asbestos, rubber, and sulphur.

In the lathe it was found to burn the edge of the cutting tool nearly as badly as hard rubber, and also to take a very rough surface so that it becomes necessary to press it in order to obtain a smooth face.

It burns with difficulty and giving an odor of burnt rubber.
It was attacked strongly by HNO_3
" " " " H_2SO_4 leaving asbestos residue after washing
amounting to about 20% by weight.
Not affected chemically by H_2O but absorbs fairly.
Slightly soluble in CS_2. (about 10% by cover)
Not affected by NH_4O, $C_{10}H_{16}$, naphtha, paraffine oil or spermit in one days trial.

To determine the winding of a phonoplex coil to have 114 ohms res, and 3410 turns, over a diameter of 0.813".

Let x be the ~~diam~~ diam. of the wire in ~~cmil~~ mils
x^2 " " area - - - circ. mils
c " " covering in mils
$(x+2c)^2$ " " area of wire in circ. mils.
Let L - - length of the coil in mils
Then $\frac{L}{x+2c}$ = no. of turns in the layer.
with n layers, the no. of turns = $\frac{nL}{x+2c}$.
The diam of the mean turn will be $d + n(x+2c)$ mils
The length of the mean " " " $\pi\{d + n(x+2c)\}$ mils.
" total length = $\frac{\pi n L}{x+2c}\{d + n(x+2c)\}$ mils

The res. of this length = $\frac{\pi n L}{x+2c}\{d + n(x+2c)\} \times \frac{10}{12{,}000} \times \frac{1}{(x)^2}$

The data are $\frac{nL}{x+2c} = 3410$ $\therefore n = \frac{3410(x+2c)}{L} = \frac{3410(x+2c)}{3900}$

and $\frac{3410\,0\pi}{12{,}000\,x^2}\{d + n(x+2c)\} = 114$

$$107{,}200\{850 + 0.875(x+2c)^2\} = 16800x^2$$
$$(850 + 0.875x^2 + 2.1x + 1.039)$$
$$107{,}200(0.875x^2 + 21x + 1.039) = 16800x^2$$
$$93700x^2 + 2{,}250{,}000x + 1{,}168{,}000 = 16800x^2$$
$$76900x^2 + 2250000x = -1{,}168{,}000$$
$$x^2 + 29.26x = -1.90$$
$$x^2 + 29.26x + 214 = -887.6$$
$$x + 14.6 = \mp 29.0$$
$$x = 43.6$$

#19 BWG 0.042"

$3900 \div 54 = 72$ turns = 47 layers, mean diam = $2.54 + 0.81 = 3.35$"
$= 0.28$ feet circ. $\times 3410$ turns = 3000 feet @ 0.00585 = 17.55.

Next size BWG #18 0.049" = 0.061" cond = 60 turns per layer = 57 layers.
Mean diam $0.813 + 3.48" = 4.29" = 0.3575$ ft $= 1.123$ ft @ $\times 3410$ turns = 3830 ft.
@ 0.0043 = 16.5 w.

Next 2 sizes BWG #16 0.065 = 0.077" cond = 50 turns per layer = 68 layers
Mean diam $= 0.813 + 5.24 = 6.05" = 0.504$ ft $= 1.58$ ft @ $\times 3410$ turns = 5400 ft
@ 2.44×10^{-3} = 13 w.

#17 next size.

#17 BWG = 0.058" = 0.070" cond. 55 turns per layer = 62 layers
Mean turn = $0.81 + 6.24 = 5.15" = 0.43'$ = 135 ft per turn @ 3410 turns = 4600 ft
@ 3.07×10^{-3} = 14.140

62 layers of 55 turns each #17 BWG 0.058" cond to 0.070"

Comparison of inductance between an ordinary phonoplex induction coil, and three experimental bobbins

Phonoplex coil length between flanges 10 cm. Diam: of wire over 1·2 diameter of hard rubber cylinder over core 1·42. Diam: over braiding 3·5 19 layers of 18# turns # 23 wire B.W.G. 0·025" cond to 0·030".

Bridge	Res:	Capy:	Inductance Quadrant	Kilometer	T.B.
1000/1000	7.187	1.71 †	0·1229	1229	

3 coils of same size wire, uncovered wound over iron wire on periphery of wooden solid cylinder. Diam: over wire 12·8 + breadth between flanges 9·85 120 turns of wire in a single layer.

No.	Bridge	Res:	Capy	Inductance Quadrant	Kilometer	T.B.	Position of coil	Average Kilometer per coil
1	1000/10	8·347	1.130	0·00944	94·3			31·4
2		8·352	1·335	0·0715	115·			38·3
3		8·359	0·918	0·00767	76·7			25·6
4		2.832	1·098	0·0031	31·1		One coil above removed from other	31·1

To find the number of # 35 B.W.G. that must be stranded to make the equivalent of a # 23 wire.

35 = 0·005" = 25 c.mils.
23 = 0·025" = 625 " " equivalent to 25 # 35s.

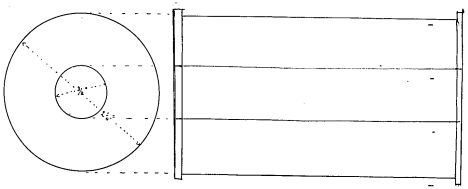
420 feet of # 23 = 10500 feet of # 35. in all.

On the winding of a phonoplex magnet required to have the maximum discharge with swiftness.

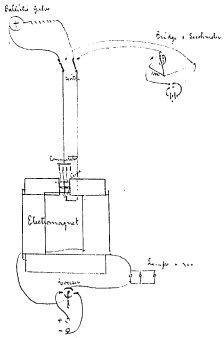
The discharge value of a coil apparently depends upon $\frac{L}{R}$ and this is independent of the length but varies with the square of the diameter of the iron core so long as the field in the latter is maintained sensibly uniform. To force more current into the present coil of 7·4 res: and 1·5 amp: is to over-heat, for its wire surface is now about 110 sq. cm. and the Watts 16 = 7·4 cm per Watt. We may therefore take the existing length of coil, increase the diam: of core to 0·75" and the ext: diam: to 2·5". Throw with 12 Nat-Hol cells @ 1·5 amperes. The res: of the cells (phonoplex type) 0·03 each = 0·36 ω and the coil 5·24 ω. The ext: diam: over rubber will be 2·05 cm. and the exterior of core 6·35 so that the coiling space = 0·7854 × 10 × (40·32 − 16·20) = 7·854 × 36·12 = 283·7 c.c.

$$\therefore d = -\frac{b}{2} \pm \sqrt{\left\{0.0004 + 0.00153\sqrt{\frac{283.7}{5.1}}\right\}}$$
$$\pm \sqrt{\left\{0.0004 + 0.00153\sqrt{55.64}\right\}}$$
$$\pm \sqrt{\left\{0.0004 + 0.00153 \times 7.46\right\}}$$
$$\pm \sqrt{\left\{0.0004 + 0.01142\right\}}$$
$$= 0.01 \pm \sqrt{0.01182} = \pm \cdot 1087$$
$$= 0.099 \text{ cm.}$$
$$= 0.039''$$

nearest = # 19 B.W.G. 0·042" cond to 0·052" × 5·10 = 872 feet; 75 turns per layer
Mean layer 0·433 fr circum. 32 feet in layer = 29 layers

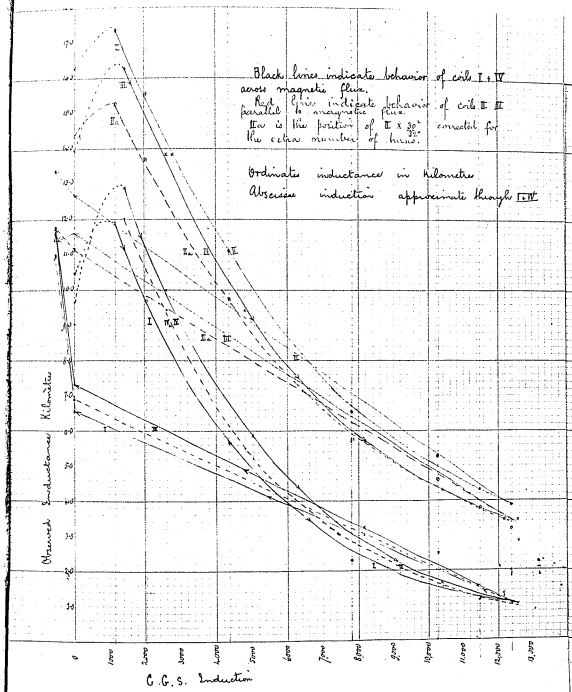


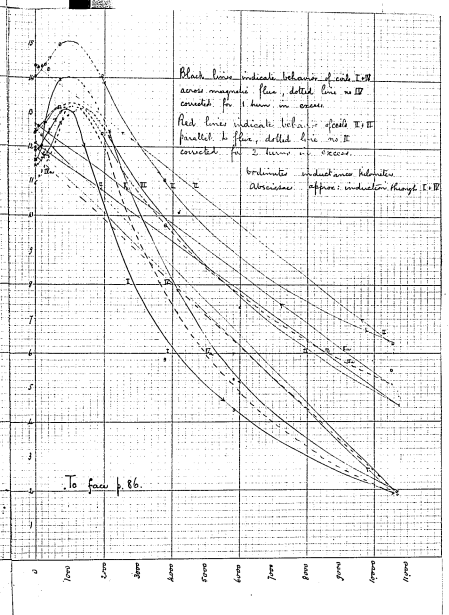
#20 B.W.G = 0·035" 0·045" cond = 85 turns per layer
= 600 feet = 16½ layers



gb·3 dis represent $1{\cdot}4224 \times 10^{8} \times 1{\cdot}0 \times 10^{-15}$ gr. = $1{\cdot}4224 \times 10^{-7}$
1 - represents $1{\cdot}4278 \times 10^{-7}$

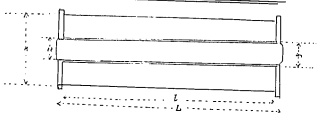
n - thus $5{\cdot}270 \times 10^{14} \times 1{\cdot}4278 \times 10^{-7} = 7{\cdot}788 \times 10^{7}$ bris
+ $1{\cdot}527 \times 10^{13} \times 1{\cdot}4278 \times 10^{-7} = 2{\cdot}257 \times 10^{6}$


Black lines indicate behavior of coils I + IV across magnetic flux.
Red lines indicate behavior of coils II + III parallel to magnetic flux.
Here is the position of II x 90° corrected for the extra number of turns.
Ordinates inductances in kilometers
Abscissae induction approximate through I + IV
Measured Inductance Kilometers
C.G.S. Induction


Black lines indicate behavior of coils I + IV across magnetic flux, dotted line no IV corrected for 1 turn in excess.
Red lines indicate behavior of coils II + III parallel to flux, dotted line no II corrected for 2 turns in excess.
Ordinates inductance kilometers
Abscissae approx: induction through I + IV

To face p. 86.

Inductance Measurements.



Bridge 1000/1000 T.B. 26.3.10

No.	Description	Dimensions L	l	x	y	z	diam. of outer	diam. of inner	zero correc.	Res. including bar w	Coil Res. at 0°C ρ	Inductance Quadrant	Reluctance	Res. @ 24°C w	Inductance Corrected $\frac{L}{R}$ Seconds
1	Phosphor	10·9	9·9	3·9	1·115	1·25	0·025	0·030	0·025"	7·16	1·82	0·1303	1303	7·05	0·0185
2	"	10·9	9·9	3·9	1·14	1·15	0·025	0·030	0·025	7·415	1·775	0·1317	1317	7·305	0·0180
3	steel	11·0	10·1	3·75	1·3	1·2	0·025	0·030	0·015	5·592	1·140	0·0638	637·7	5·42	0·0116
4	Phosphor	10·5	9·8	3·75	1·55	1·3	0·025	0·030	0·025	7·224	1·830	0·1322	1322	7·114	0·0186
5	Phosphor recent							1000/1000	Front face	104·755	1·60	0·1676	1676	104·644	0·00153
									Back "		1·93	0·2022	2022	104·644	0·00193

Experiment with iron cube on the direct scale of reluctance in magnetised iron

Nov. 14th

Cube placed between poles of electromagnet and following obs. taken.

No. Expt.	Bridge	Coil tested	Res. of coil & cable	Coil by Wheat	Inductance Reluctance	Adjustment of quadrant to correct for reluctance	Number of magnetic Ballistic	Galv.	Mean Phase	Res. of galv. at	ρ	Adjustment cable and by coil	L	μ	Mean μ
1	comp.	1	2·198	0·360	10·43	0						270			
		2	2·969	0·550	12·33	10·34						260·3			
		3	2·853	0·490	13·98							245·7			
		4	2·930	0·330	9·17	7·20						271·4			
2		1	2·897	0·410	11·89	0·1 amp	82	93	92·5		6·44×10⁻⁶	318 mm	1190		
		2	2·968	1·585	17·36	15·16						1b			
		3	2·854	0·570	16·27							30	1350		
		4	2·927	0·440	12·28	11·05						31			
3		1	2·899	0·255	9·77	0·17 amp	143	143	143		7·88×10⁻⁶		1470		
		2	2·967	0·225	10·38						1·16×10⁻⁶		2060		
		3	2·856	0·485	13·83										
		4	2·926	0·340	9·95								2350		
4		1	2·898	0·195	5·24	0·28	105	102	104	8270	1·48×10⁻⁶		2890		
		2	2·965	0·375	11·12						2·38×10⁻⁶		4350		
		3	2·848	0·320	9·40										
		4	2·925	0·200	5·85								4910		
5		1	2·900	0·220	2·55	0·5	187	188	187·5		2·61×10⁻⁶		7836		
		2	2·973	0·220	6·54						4·32×10⁻⁶				
		3	2·855	0·200	5·71										
		4	2·928	0·110	3·29										
6		1	2·900	0·075	2·17	1·0	244	244	245		5·52×10⁻⁶		10240		
		2	2·973	0·075	2·25										
		3	2·866	0·150	4·34										
		4	2·940	0·055	1·62										
7		1	2·899	0·040	1·16	1·5	275	275	275		6·20×10⁻⁶		11490		
		2	2·976	0·065	1·91										
		3	2·868	0·120	3·42										
		4	2·922	0·065	1·92										
8		1	2·899	0·025	1·00	10 amp	298	295	296·5		6·69×10⁻⁶		13,100		
		2	2·978	0·025	3·86										
		3	2·858	0·100	2·85										
		4	2·921	0·025	1·02										
9		1	2·900	0·227	0·658	0	295	310	302·5		6·92×10⁻⁶		12,550		
		2	2·974	0·227	1·270										
		3	2·858	0·207	1·160										
		4	2·924	0·200	0·734										
10		1	2·902	0·400	11·61										
		2	2·974	0·450	12·38										
		3	2·858	0·400	11·43										
		4	2·924	0·400	11·73										

1 Ohm at temp 28°C. thus galv. = 1 ρ = 96·3 mean phase

The excess of induction through 4½ over 1 is partially due to the fact that 1 & 2 were above 3 & 4 bench & that the pole faces slightly approached downwards letting the cube rest slightly wedged below.

Red figures are values of ρ corrected for extra 1 turns

1 16 c.p. burner vitiates the air to the same degree as five persons

1 c.p. gas vitiates equivalent to 0.312 persons.

1 c.f. - burnt per hour - - 1 -

A room 30 ft square = 900 sq. feet = 836100 sq. cms.

its candle power n = $8.36 \times 10^5 \times 3.12 \times 10^{-4}$ = 261 c.p. brilliant (it would be moderately) lighted by one third of this = 87 c.p. say 5 jets of 16 c.p.

Its volume would be 135000 c.f. = $1.35 \times 10^8 \times 2.83 \times 10^{-4}$ c.c.

= 3.82×10^7

80 c.p. raise 5600,000 c.c. of gas air 1°C. per sec.

10,080,000 - - - - 1°F - -

- - - 3,360,000 - - - - 30°F - -

$\frac{3.82 \times 10^7}{3.36 \times 10^6}$ = 11.37 seconds for the whole room.

= 19 mins.

Problem: A room of given dimensions is lighted by gas in sufficient abundance for good illumination. Required the temperature of the room after a given interval and also the corresponding temperature with incandescent lamp equivalent illumination.

Let V be the volume of the room (c.c.)

a its area (sq.cms)

h its height (cms)

Then allowing Preece's rule of 1 Watt per 1000 sq. cms. (10 Watts per sq. metre) of floor space = 0.001 Watt per sq cm

so that if W be the Watts required

$W = 0.001\,a$

and the total illumination in c.p. will be $\frac{W}{3.2} = 0.000312\,a$.

so that if n be the number of candles required

$n = 0.000312\,a$

For 16 candles power the average volume of gas consumed is 5 c.f.

so that for 1 c.p. 0.312 c.f. of gas are consumed per hour

for n = $0.000097735\,a$ c.f.

1 c.f. of gas produces in combustion 850 B.T.U. units

$= 8.50 \times 1.058 \times 10^{10}$ ergs

$= \frac{8.50 \times 1.058 \times 10^{7}}{4.2}$ gramme calories (therms)

$= 2.14 \times 10^{6}$ therms.

1 c.f. in gas $= 6.68 \times 10^{4}$ therms per hour

= 1113 - - mins

= 18.5 - - second.

1 c.p. in an Edison lamp takes 3.2 Watts

= 0.762 therms per sec.

= 45.7 - - mins.

so that 1 c.p. in gas gives 24 times as much heat as 1 c.p. of incandescence.

The specific heat of air being 0.238 one therm will raise 4.2 grammes of air 1°C. or 1 Watt will raise 1 c.c. of air 1°C. per sec.

and 1 gramme of air occupies 784 c.c. @ 0°C or $784\left(\frac{313}{273}\right) = 900$ c.c. @ 30° C. consequently each candle power of incandescence raises 2880 c.c. of air 1°C.

- gas. " 70000 - - -

consequently n c.p. in gas raise $70,000\,n$ c.c. of air 1°C. per sec.

n - - incandescence - $2900\,n$ - - - - - -

∴ the whole volume of the room being abh

the air in it will be raised 1°C. in $\frac{abh}{70,000\,n}$ seconds by gas

and $\frac{abh}{2900\,n}$ - - incandescence

substituting for n $3.12 \times 10^{-4}\,a$

the room will be raised 1°C in $\frac{h}{70 \times 10^{3} \times 3.12 \times 10^{-4}}$ seconds by gas

and $\frac{h}{2.9 \times 3.12 \times 10^{-1}}$ - - incandescence

$= h/21.84$ by gas and $10\,h/9.05$ by incandescence

$= 0.046\,h$ seconds - - $1.105\,h$ seconds - -

A room 15 feet high = 4500 cms. would be raised 1°C in 206 seconds by gas

- 4980 - - mins

Experiment with iron cube on the Direction of Reluctance in magnetised iron.

November 15th Rules placed between poles but separated on each side by square sheets of hard rubber 0·2(5 in) thick, and following obs. taken.

Date	Bridge	Block Board and Rule	Rim. Ohms of coil & lead	Ratio for balance R	Induc. Henries	approx. C in c.m. sec. amp	Throw of Ballistic Galv. +	−	Mean Ballistic throw	Rim in Galvanom.	φ	approx. mean φ	L	μ	mean μ
1	100 cycl.	1	2·902	0·415	12·05							270			
		2	2·983	0·473	12·11	0·11						264·3		III	11·96
		3	2·881	0·400	11·52							245·7			
		4	2·984	0·400	11·62	0·98						274·9		IV	11·47
2		1	2·903	0·405	11·76							30			
		2	2·983	0·467	13·93	0·05 0						30		III	11·89
		3	2·890	0·400	11·52							30			
		4	2·984	0·400	11·63	0·94						31		IV	11·33
3		1	2·907	0·410	11·92							102·9			
		2	2·984	0·480	14·32	0·07	+5	7	3	5270	2·77 x10⁻⁶	102		III	12·07
		3	2·885	0·400	11·54										
		4	2·986	0·480	11·95	0·19	8	9	3		2·77 x10⁻⁶	102·2		IV	11·56
4		1	2·907	0·420	12·21	0·08	9	11	4·8		4·44 x10⁻⁶	164·6			
		2	2·988	0·480	14·34	0·10						167		III	12·07
		3	2·886	0·400	11·54										
		4	2·911	0·400	11·62	0·19	7	8	3·8		3·21 x10⁻⁶	129·4		IV	11·70
5		1	2·908	0·425	12·36	0·09	8	9	4·3		3·99 x10⁻⁶	147·6			
		2	2·989	0·480	14·34	0·10						136·6		III	12·07
		3	2·886	0·400	11·54										
		4	2·912	0·415	12·09	0·33	7	9	4·0		3·70 x10⁻⁶	128·4		IV	11·85
6		1	2·907	0·425	12·36	0·11	11	12	5·8		5·39 x10⁻⁶	198·9			
		2	2·989	0·480	14·34	0·10						199·3		III	12·15
		3	2·886	0·415	11·69										
		4	2·912	0·415	12·09	0·33	11	12·5	5·9		5·46 x10⁻⁶	200·9		IV	11·95
7		1	2·912	0·430	12·53	0·14	18	16	7·3		6·57 x10⁻⁶	243·7			
		2	2·994	0·480	14·38	0·10						248·8		III	12·23
		3	2·887	0·400	11·53										
		4	2·916	0·435	12·69	0·34	13	16	7·3		6·57 x10⁻⁶	246·9		IV	12·21
8		1	2·911	0·425	12·38	0·18	22	24	11·8		10·65 x10⁻⁶	394·5			
		2	2·992	0·475	14·23	0·51						395·1		III	12·11
		3	2·891	0·400	11·71										
		4	2·915	0·427	12·45	0·16	23	24	11·8		10·93 x10⁻⁶	401·7		IV	12·00
9		1	2·909	0·447	13·01	0·25	43	44	21·8		20·19 x10⁻⁶	747·5			
		2	2·988	0·500	14·94	0·14						752·8		III	12·93
		3	2·888	0·440	12·71										
		4	2·913	0·480	13·99	0·34	43	46	22·3		20·63 x10⁻⁶	758·2		IV	13·01
10		1	2·910	0·370	10·77	0·50	104	109	52·3		50·27 x10⁻⁶	1862			
		2	2·988	0·470	14·05	0·35						2063		III	12·31
		3	2·887	0·425	12·27										
		4	2·913	0·427	12·44	0·45	126	124	63		5·53 x10⁻⁶	2166		IV	11·21
11		1	2·910	0·300	9·82	1·0	219	221	110		1·08 x10⁻⁶	3771			
		2	2·989	0·370	11·26	0·75						3916		III	9·91
		3	2·886	0·350	10·10										
		4	2·911	0·370	7·96	0·76	244	241	122		1·12 x10⁻⁶	4152		IV	6·53
12		1	2·910	0·150	4·36	2·0	116	118	58·5	10000 + 5270 = 15270	1·05 x10⁻⁶	5812			
		2	2·989	0·200	5·976	1·5						5905		III	6·31
		3	2·886	0·255	7·323										
		4	2·911	0·170	4·950	2·4	120	123	60·5		1·63 x10⁻⁶	5997		IV	4·50
13		1	2·913	0·165	4·894	2·0	224	220	106		2·43 x10⁻⁶	16·530			
		2	2·990	0·210	6·174	1·5	0					16·65		III	5·80
		3	2·886	0·155	4·472		0								
		4	2·912	0·170	4·888	2·4	213	221	108·5		2·41 x10⁻⁶	16·700		IV	4·96
14		1	2·910	0·410	11·93	0									
		2	2·990	0·480	14·35	0·13								III	12·38
		3	2·885	0·420	12·13										
		4	2·913	0·420	12·53	0·34								IV	11·84

1 Block all 23·5°C 1 before test mean throw 81·8 after test 81·0 mean 81·4

81·4 divs represent $1·430 \times 10^{7} \times 1·0 \times 10^{-16} = 1·430 \times 10^{-7}$ abs qp

1 - - $1·756 \times 10^{-7}$ - -

d - - $1·756\ d \times 5·270 \times 10^{3} = 9·256 \times 10^{3}$ lines

and $1·756\ d \times 1·927 \times 10^{3} = 2·652 \times 10^{3}$ -

Res. of each end of Galv. 2690 Res. unit 0.02452

No. in ½	Time	Mean Thermo Rdg	Mean amperes	Res. in cst. unit	Total res. in cst. unit	Res. of ½	R/r	Rise of temp °C	C°	Rad. per cm.	Energy per cm.	Radiation per cm.	Radiation per cm.	Temp. air
1	20.00/50	0.0132	1.08	4420	7110	0.06555				0.000178				25.2°C
	22.00/50	0.067	5.46	4525	7215	0.0658	1.0125	3.22	29.81	0.000104	0.001262	0.001362		26°C
	24.00/21.00	0.2655	21.65	5550	8240	0.0754	1.156	4.02	468.7	0.000125	0.001760	0.07026		
	21.00/15	0.5140	41.93	9125	11815	0.1077	1.657	169.4	1758	0.000791	0.03119	0.2465		
	15	0.013	1.08	4450	7140	0.06572				0.000-1013				26.5°
2	20.00/50	0.067	5.46	5780	8470	7792			29.81	1.307				25.2
	22.00/21.00	0.2655	21.65	7890	10470	7792			468.7	1.307				
	24.00/15	0.5144	41.93	5665	8245	7.945	1.019	4.9	1758	1.333	0.02343	0.00585	0.01758	
	15	0.013	1.08	5750	8440	7.918			1	—				
	20.00/50	0.777	63.36	5290	7980	8.270	1.0408	15.6	4.01×10³	1.387	0.0587	0.0273	0.0463	
	22.00/50	0.891	72.66	5160	7850	8.406	1.078	20.1	5.220	1.440	0.0744	0.0352	0.02986	
	24.00/50	1.076	87.72	4805	7495	8.806	1.129	33.3	7.695	1.477	0.1137	0.05829	0.0565	
	26.00	1.166	95.05	4610	7300	9.040	1.159	41.0	9.034	1.516	0.1370	0.07176	0.07194	27.2°
3	20.00/50	0.067	5.46	1070	3760	1.7550			29.81	3.018×10⁻⁴				
	22.00/50	0.2655	21.65	982	3672	1.797	1.024	6.2	468.7×10⁻⁴	3.087	0.01447			25.2
	24.00/15	0.514	41.93	782	3472	1.929	1.099	25.5	1.758×10⁻³	3.314	0.05927			
	15	0.013	1.08	1070	3760	1.755	—		1.06					
	20.00/50	0.777	63.36	349	2039	2.172	1.238	61.4	4.01×10⁻³	3.731	0.1498			
	22.00/50	0.891	72.66	195	2885	2.316	1.320	82.5	5.220	3.979	0.2101			
	24.00/50	1.076	87.72	130	2880	2.627	1.497	128.1	7.695	4.513	0.34714			
	26.00	1.166	95.05	375	3065	2.776	1.582	150.0	9.034	4.809	0.4305			27.2
4	20.00/50	0.067	5.46	3050	5740	1.15×10			2.981×10⁻³	1.04×10⁻³				
	22.00/50	0.2655	21.65	2990	5680	1.162	1.006	1.5	4.687×10⁻³	1.046	0.00981			25.2
	24.00/15	0.514	41.93	3350					1.758×10⁻³					
	15	0.013	1.08	3000	5690	1.160	1.005	1.5	1.16					
	20.00/50	0.777	63.36	2400	5090	1.297	1.123	31.7	4.01×10⁻³	2.217	0.0703			
	22.00/50	0.891	72.66	2230	4920	1.341	1.161	41.5	5.220	2.292	0.12.10			
	24.00/50	1.076	87.72	1900	3590	1.838	1.590	132.6	7.695	3.112	0.2419			
	26.00	1.166	95.05	1700	3390	1.947	1.656	176.4	9.034	3.329	0.3098			27.2

Experiment on the Radiation of heat from wires carrying currents as a function of their absolute temperature 16th November 89.

(91)

Four bare bright copper wires were suspended across the room as in the experiment detailed at the commencement of this book. They were connected in series and their resistances measured by comparison with the grid after passing different current strengths through them for two or three minutes; the temperature of the air near the wires and probably the mean temperature of floor walls, objects + ceiling rising from 25° to 27°C. These measurements having been taken the steam was cut off the building; all windows and doors widely opened and air allowed to circulate through the building for 30 minutes the external temperature being 0°C. The windows were again closed and the measurements repeated as speedily as possible the temperature rising from 8° to 15°C. The following were the results obtained.

No. of wire	Length Metals	Diameter Diam.	Area Cir. mils	Sq. cms.	Surface per cm. sq. cms.	Res. per cm. to 25°C	Resistance per cm. to 0°C	Resistivity	Conductivity $\frac{1}{\rho}$
1	601.5	0.057	0.1448	3,250	0.01647	0.06549	0.0001078	0.0000925 e.g. 1×10^{-6}	1618
2	576.3	0.1645	0.418	27,600	0.1372	0.13130	1.307×10^{-5}	1.192×10^{-5}	1635
3	582.2	0.108	0.2743	11,640	0.05910	0.8616	3.018×10^{-5}	2.728×10^{-5}	1625
4	585	0.134	0.34024	17,960	0.09102	1.0697	1.966×10^{-5}	1.792×10^{-5}	1631

No. in ½	Time	Mean Thermo Rdg	Mean amperes	Res. in cst. unit	Total res. in cst. unit	Res. of ½	R/r	Rise of temp °C	C°	Rad. per cm.	Energy per cm.		
1	22.00/50	0.0135	1.09	4020	6670								
	24.00/50	0.2619	21.35	5090	7740								
	26.00/21.00	0.5323	43.89	5570	8220								
	21.00/15	0.7385	60.22										
	15	0.0856	8.4.44										
	20.00	1.142	93.10										
	22.00	0.0212	2	4100	6750								
2	22.00/50	0.0135	1.1	6110	8760	7.420							
	24.00/50	0.2619	21.35	6150	8800								
	26.00/21.00	0.5382	43.89	5900	8550								
	21.00/15	0.7385	60.22	5140	8140								
	15	0.0856	8.4.44	5160	7810								
	20.00	1.1142	93.10	4860	7510	8.656	1.1656	20.1					
	22.00	0.0216	2	5370	8620	7.542	2	25.77					
3	22.00/50	0.0135	1.1	1250	3900								
	24.00/50	0.2619	21.35	1160	3810								
	26.00/21.00	0.5382	43.89	855	3505								
	21.00/15	0.7385	60.22	380	3030								
	15	0.0856	8.4.44	-65	2495								
	20.00	1.142	93.10	-235	2295								
	22.00	0.024	2	1180	3820								
4	22.00/50	0.0135	1.1	3300	5950								
	24.00/50	0.2619	21.35	3210	5860								
	26.00/21.00	0.5382	43.89	3000	5650								
	21.00/15	0.7385	60.22	2510	5160								
	15	0.0856	8.4.44	2115	4760								
	20.00	1.1142	93.10	1940	4590								
	22.00	0.022	2	3150	5800								

Speculations on the dimensions of electrical quantities, and on the nature of electrical action.

Since electricity can have one and only one nature, it is necessarily untrue that the dimensions of any electrical quantity say current can be different according to the system of units by which it is measured, and Professor Rücker has shown that the ratio v between the electrostatic and electromagnetic units problably arises from ignoring the dimensions of κ and μ.

Although the quantity of electricity can hardly be of the nature of a mass since it does not appear to be a function of gravitation, it must be in all probability directly connected with a mass, for all forms of energy seem to be mass-movement. Thus it should be independent of time. For example it might resemble a wheel capable of delivering and manifesting energy by changes in its motion, and to complete the analogy its dimensional expression might be that of moment of mass ML. If this hypothesis be accepted we have from the fundamental statical equation $f = \frac{q^2}{\kappa d^2}$

$$q = f^{\frac{1}{2}} \kappa^{\frac{1}{2}} d = ML$$
$$= L^{\frac{1}{2}} M^{\frac{1}{2}} T^{-1} L \kappa^{\frac{1}{2}} = L^{\frac{3}{2}} M^{\frac{1}{2}} T^{-1} \kappa^{\frac{1}{2}}$$
$$\therefore \kappa = L^{-1} M T^{2}$$
$$c = q/t = ML T^{-1} = \text{mass motion, \& absolute or relative}$$
$$\varepsilon = w/q = ML^{4} T^{-2} L^{-\frac{3}{2}} M^{\frac{1}{2}} T^{-1} \kappa^{\frac{1}{2}} =$$
$$= A_{\mu} T^{-2} = \text{acceleration in angular velocity.}$$
$$r = \varepsilon/c = T^{-2} M^{-1} L^{-1} T$$
$$= L^{-1} M^{-1} T^{-1}$$
$$s = \frac{q\kappa}{\varepsilon} = ML L^{-1} M T^{2} T^{2}$$
$$= M^{2} T^{4}$$

A current on this supposition has the nature of momentum, while an electromotive force has an acceleration in angular velocity, resistance, electrostatic capacity, and permittivity are meaningless.

Also since $\frac{1}{2}\mu c^2 = L^2 M T^{-2}$ and $c^2 = M^2 L^2 T^{-2}$

$$\mu = M^{-1}$$

and also since $\frac{1}{\sqrt{\kappa\mu}} = \frac{L}{T}$

$$\kappa = L^{-1} M^{-1}$$
$$\therefore \mathcal{L} = L$$

so that the inductance is still a length, but should always be multiplied by the reciprocal of a mass, which, combined with the square of current it becomes energy.

Measurement of the electrochemical equivalent of zinc.

23. X. 89 to 30. X. 89. Observer Schmalen

Two small meter bottles set up with plates 0.62 × 2.5 × 3.76 cm amalgamated but in solution of pure $ZnSO_4$. 1.054 drops acid.

No. of Obs.	Weight after heat	Weight after heat	Difference Gain	Weight Loss	Time elapsed	Mean current	Mean density of C.	Mean transfer	Electrochemical equivalent	Atomic Wt. of Zinc.
1	49.4048	48.8116		0 - .5932						
2	47.7114	48.2056	0.5942	.5942 (0)				0.5950	0.3246 × 10⁻²	62.46
3	49.6139	50.2097	0.5958	.5958 (0)						
4	48.4023	47.8068		0 - .5955				2.0515		
5	11.9751	12.9239		2.0512						
6	16.9780	19.0298	2.0518							

Keeping 38 amperes (divided among) 28 spools at 110 volts all in series gives 2.900 ω for the whole circuit = 0.1036 ω for each spool.
Will the value

$$d = -0.01 \pm \sqrt{\left\{0.0004 + 0.00153\sqrt{\frac{2170}{0.1036}}\right\}}$$
$$\pm \sqrt{\left\{0.0004 + 0.00153\sqrt{20940}\right\}}$$
$$+ 0.00153 \times 144.7\}$$
$$+ 0.2214$$

$$\pm \sqrt{0.2218}$$

$$\pm 0.471$$

$$= 0.461 \text{ cm}$$
$$= 0.181'' \quad = \# 7 \text{ B.W.G.}$$

ft per ω = 3140 ∴ 325.0 feet = 209 turns = 7600 A.T. per spool
cover = 0.195" = 37 turns per layer = 5½ layers = 1.2" dep.
energy 38" × 0.104 = 150 watts ÷ 1065 sq. cm = 7 sq. cm per watt.
wt. = 0.1036 × 307.8 = 31.9 lbs.

20 lbs of wire are to have a res. of 0.1036.
1 " " " " " 0.00518 " #5 nearest size

ft per ω = 2640 = 290 feet = 179 turns @ 35 amp = 6275 A.T.
0.11 ω × 28 = 3.08 ω in all @ 110 volts = 35.7 amperes.
the feet lbs per ω = 217.3 × 0.11 = 23.90 lbs. = 670 lbs on 28 spools

Magnetic induction through a large one milling electro-magnet of horse shoe shape.

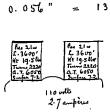
(99)

Diam. of core 13 cm = 133 sq. cms. cross sectional area.
5 turns of wire led to ballistic galvanometer with 12,200 ω added = 17500 ω in all reversals give 235 divs. = 117.5 divs for induction
1 G.B. 1¢ = 80 divs.
∴ $1.43 \times 10^4 \times 10^{-15}$ give 80 divs ∴ 1 div represents $1.43 \times 10^{-7}/0.80 \times 10^2$
$= 1.8 \times 10^{-9}$ units of quantity.
117.5 divs = 211.5×10^{-9} = 2.115×10^{-7} units.
∴ $2.115 \times 10^{-7} \times 1.75 \times 10^{13} = 3.70 \times 10^6$ lines ÷ $1.33 \times 10^2 = 2.8 \times 10^4$
÷ 5 = 5600 lines per sq. cm.
On laying the one in bulk over the pole on wood 0.225" thick the throw increased to 2140 divs; and on laying a strip of iron at about the same distance from the pole it increased to about 320 divs.
The spools of wire on these magnets have an internal diam of 5.25" an external diameter of 7.13" and are 7.25" interflange. The wire is 0.021" covered to 0.040" about 155 turns to the layer and about 28 layers and 18 lbs in all. so that the total number of turns on each spool is about 3,87,50
By trial it was found that the right excitation was obtained with about 18 amperes through 8 spools in multiple arc = 1625 amperes through each, so that the amperes-turns to be supplied are 2 × 3875 × 1.63 = 12,630 say 12,000. The radiating surface is 7.25 × 3.142 × 7.13 × 6.45 = 1065 sq. cms and the energy 1.63 × 1.63 × 55 = 146 Watts. 7.3 sq cms per Watt, so that even though the magnet might be reduced in diameter, the surface of the wire cannot be reduced.
To supply 150 Watts from 500 volts the current must be 2.73 amp. and the res: 20.15 ω.
The winding space will be 0.7854 (18.11" − 13.33") 18.142 = 2170 cc
Consequently the diameter of wire will be

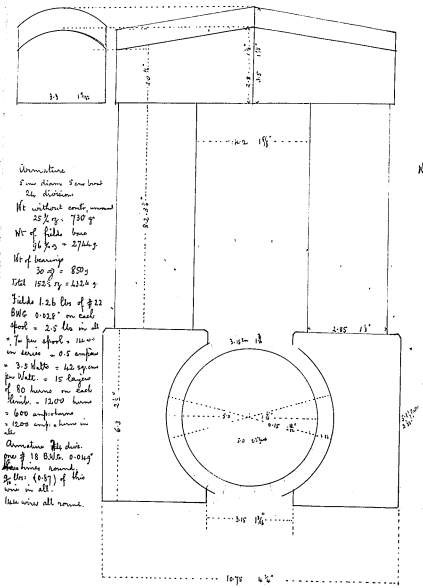
$$d = -0.01 \pm \sqrt{\left\{0.0004 + 0.00153\sqrt{\frac{2170}{20.15}}\right\}}$$
$$\pm \sqrt{\left\{0.0004 + 0.00153\sqrt{107.7}\right\}}$$
$$\pm \sqrt{\left\{0.0004 + 0.00153 \times 10.38\right\}}$$
$$\pm \sqrt{(0.0004 + 0.01588)}$$
$$\pm \sqrt{0.01628}$$
$$\pm 0.1276$$
$$+ 0.1176 \text{ cm} = 0.046''$$

17 B.&S = 0.0452

These diam: covered will be 0.060 and there will be 120 turns per layer. The mean diam: = 15.72 cms and mean circum: 49.4 cms. = 1.62 ft and the total number of feet will be about 4200 so that the number of layers being 16 = 1920 turns =
18 BWG = 0.049" @ 230 ft per ω = 4635 feet ÷ 1.62 = 2860
turns × 2.73 = 7810 ampere turns.
19 BWG = 0.042" @ 170 ft " " = 3595 feet. ÷ 1.62 = 2220
turns × 2.73 = 6060. Covered this wire will have a diam: of 0.056" = 130 turns per layer = 17½ layers = 0.98"



19.5 lbs of # 19 BWG. on each spool
4 magnet = 28 ~~amps~~ spools = 550 lbs.
Total current at 110 volts = 38 amperes.
Magnets of cast iron present dimensions.



Experiment to determine the effect of magnetisation on the gravitation pull.

Took a short cylinder of chaus stub steel 11.0 cms long and 0.1505" and 0.3823 cms diam. without any decided magnetisation and after letting it dry over H_2SO_4 carefully weighed it — 11.0135 grammes, the zero being then +1. Put 20 ampère through the large magnet and laid over its pole a strip of chamois leather, put the steel bar down on this strip for a few moments and then returned it to the scale pan. The balance was still 1.0+. Disturbing the rider 0.2.5 mgms threw the zero to 3.5 — so that 4.5 corresponds to 0.25 mgms and 1 to 0.055 mgms. It is probable therefore that if the weight had altered by 0.055 mgms and almost certain that if it had altered by 0.1 mgm the difference would have been detected. That is to say a certainly probable difference of 1 in 119135 = 0.0009(1/10)% or probably a difference of 1 in 200,200 = 0.0005 (1/2000 %)

The moment of inertia of the needle is approximately

$$11.014\left(\frac{12.1}{12}+\frac{0.1146}{4}\right) = 11.014\,(1.0083+0.0365)$$

$$= 11.014\,(1.0448) = 11.51 \text{ cm}^2 \text{ gms.}$$

The bar's period of vibration was found after the experiment to be approximately $\frac{305}{32} = 9.53$ sec. and with H = 0.189

$$M = \frac{\pi^2 \times 11.51}{9.53^2 \times 0.189} = \frac{9.87 \times 11.51}{90.83 \times 0.189} = \frac{1101.0}{17.17} = 64.1$$

$$I = \frac{M}{V} = \frac{64.1}{11 \times 0.7854 \times 0.3825 \times 0.3825} = \frac{64.1}{1.263} = 50.75$$

To determine the winding of a small motor to give enough power for a sewing machine, when working with a phonograph battery of 10 cells 7 volts @ 4.5 ampere. = 31.5 Watts.

Peripheral velocity 1000 ft per min = 500 cms per sec diam 6 cm = 18.84 = 26.5 revs per sec ∴ $\varphi n \times 26.5 = 7 \times 10^8$. Also the number of wire must be 6 × 24 = 144 ∴ $\varphi = 7 \times 10^8 / 144 \times 2.54 \times 10^3 = 1.91 \times 10^5$ and allowing 38% for leakage the total flux to provide for must be 2.86×10^5 say 3×10^5. The total air space is 1.15 and the area is (6.3 + 0.4) × 5 = 33 sq. cms. Hence the total air reluctance is $\frac{33}{1.15} = 28.7$. ∴ 1.25 T. at. = $28.7 \times 3 \times 10^5 = 8.61 \times 10^6$

The surface is $2.85 \times 3.14 \times 2 \times 8.2 = 147$ sq. cms on the field and allowing 25 sq. cms per watt = 6 Watts @ 6 volts = 1 ampere. With 0.5 amperes in the field coil, and a depth of 1.4 cms the winding space on each spool is $\frac{\pi}{2}(2.85+2.6) - 2.85 \times 8.2$

$$= 0.785\{(5.65)^2 - (2.85)^2\}\,8.2 = 0.785\,(31.92 - 8.12)\,8.2$$

$$= 0.785\,(23.8)\,8.2 = 153 \text{ sq. cms.}$$ and the rest of each spool must be 7.

$$d = 0.01 \pm \sqrt{\{0.00004 + 0.00153\sqrt{\tfrac{153}{7}}\}}$$

$$\pm \sqrt{\{0.00004 + 0.00153\sqrt{21.9}\}}$$

$$+ 0.00153 \times 4.68$$

$$+ 0.00716$$

$$+ \sqrt{0.00756}$$

$$+ 0.0869 \text{ cm} = 0.11$$

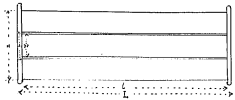
$$+ 0.0769 \text{ cm} = 0.0803$$

21 BWG = 0.032" − 0.044" cond = 70 turns per layer. Mean layer = 13.35 cms in circ = 0.438" ∴ 1 layer = 30.6 ft. and there are 700 feet = 23 layers

22 BWG = 0.028" + 0.040" cond = 80 turns per layer ∴ 35 ft × 832 ft = 15 layers = 0.66"

Armature wire # 18 BWG. 1440 turns of the drum × 10" = 1440" = 120 ft = 0.87 lbs

Inductance Measurements



No.	Description of Coil	Dimensions L	l	z	y	x	Diameter of conductor	Diameter of bent wire	Diameter of one wire	Resistance ± 0·1 mm	Capacity Resistance 25°C	Inductance Quadrants	Inductance Kilometer	Time Constant L/R in sec at temp.	Mutual Ind. Shunts		M Kilometer
1	Special coil	10·6	9·9	8·15	2·15	1·9	0·0195		No wire	166·502	0·120	0·0999	198·5	0·00120	0·072		
2	Plain single	29 layers of triple wound					0·1265	0·066	Cons.	16·402	0·121	0·0198	198·4	0·0012			
3	Plain double	26 layers of double wound								16·380	0·121	0·0198	198·2	0·0012			
4	w + b in ‖									8·243	0·243	0·0200	200·3	0·00243			
5	w + c ‖	Left hand half triple wound								5·509	0·366	0·0202	201·6	0·00367			
6	w + b series	Left = 1·243 = 2·243								32·487	0·2465	0·0801	800·8	0·002465			
7	. . . series									32·487	0·—	—	—				
8	a, b + c in series									49·2467	0·367	0·1809	1809	0·00367			
9	w + c in triple									16·402	0·2465	0·0802	401·8				
10										16·402	0·—	—	—				201·5
11	Step Plain	10·6	9·65	(3·7 + 5·95)	1·55	1·35	0·058	0·067	0·014	7·147	1·120	0·0801	800·5	0·01131			
12	Stepped with	10·6	9·9	6·15	2·15	1·9	0·0195	0·066	0·008	5·4324	3·35	0·1821	1821	0·03366			
13	Special	10·6	10·0	6·35	2·15	1·9	0·035	0·036	0·011	5·83	0·2037	0·0237	237·3	0·002144	0·100		
14		17 layers of 96 turns each								5·83	3·02	0·1761	1761	0·03073	0·800		
15	Barometric	10·6	9·3	5·70	2·35	1·8	0·035	0·036	0·010	5·577	4·13	0·2304	2304	0·04184	0·074	Length of coil	17·1
16	Special without wire	11·65	12·65	9·0	3·5	2·65	0·149	0·052	0·126	23·59	2·998	0·7072	7072	0·1387	18·49	Cons.	23
										5·152	1·115	0·0578	578	0·0713	0·082		
17	Special	0·15	4·8	6·0	2·3	1·90	0·035	0·038	0·010	5·9	3·70	0·2183	2183	0·0377	0·11	Cons.	17·1

See Book VII for data given in Phonograph Work.

* No change in the inductance of any one coil was noticed when that adjacent to it was short-circuited.

N.B. The reasoning on this page is faulty.

The most simplest case is as follows:—

A coil of resistance ρ and inductance λ is excited by a source E applied to its terminals. The source E being removed the coil is discharged without spark or loss of energy through a line of resistance r and inductance l. To find the conditions of discharge assuming no permittance in the line.

At any time t seconds after breaking contact at key

$$\lambda \frac{d^2q}{dt^2} + l\frac{d^2q}{dt^2} + (\rho+r)\frac{dq}{dt} = 0$$

$$\frac{d^2q}{dt^2}\left(\frac{\lambda+l}{\rho+r}\right) = -\frac{dq}{dt}$$

$$\therefore \frac{d^2q}{dt^2} = -\frac{1}{T}\frac{dq}{dt} \quad \text{where } T = \frac{\lambda+l}{\rho+r}$$

$$\frac{dq}{dt} = -\frac{q}{T} + m$$

$$\therefore q = \varepsilon^{\theta + \frac{t}{T}} + mT$$

when $t = 0$ $q = a$ the initial coil charge (1)

$t = \infty$ $q = 0$ (2)

$$\therefore a = \varepsilon^{\frac{\theta}{T}} + mT$$

$$= \varepsilon^{\frac{\theta}{T}} \quad \text{by (2)}$$

$$\therefore q = a\varepsilon^{-\frac{t}{T}}$$

$$c = \frac{dq}{dt} = -\frac{a}{T}\varepsilon^{-\frac{t}{T}}$$

$$\frac{de}{dt} = \frac{d^2q}{dt^2} = \frac{a}{T^2}\varepsilon^{-\frac{t}{T}}$$

The charge in the coil commencing at the value $a = C\theta = \frac{E\lambda}{\rho}$ declines logarithmically.

The current in the line and coil commencing at the value $-\frac{a}{T}$ $= -\frac{E\theta}{T} = -\frac{E\lambda(\rho+r)}{\rho T(\lambda+l)} = -\frac{E(\rho+r)\lambda}{\rho T(\lambda+l)}$ declines logarithmically.

The e.m.f. of discharge $\lambda\frac{d^2q}{dt^2}$ commences at $\frac{a\lambda}{T^2} = \frac{E\lambda^2}{\rho T^2}$

$$= \frac{E\lambda^2}{\rho^2 T^2} = \frac{E\theta^2}{T^2} = \frac{E\lambda^2(\rho+r)^2}{(\lambda+l)^2\rho^2}$$

The total energy of discharge $= -\frac{a^2(\lambda-l)}{T^3}\int_0^\infty \varepsilon^{-\frac{2t}{T}}dt = \frac{(\lambda-l)a^2}{2T^2}$

$$= \frac{E\lambda}{2}\frac{(\lambda-l)}{(\lambda+l)}\frac{(\rho+r)^2}{\rho^2} \quad \text{where } l = 0$$

Calculations for a multiplex Edison dynamo to be run direct from an engine at 220 revolutions per minute

Nov. 21st 89

The peripheral speed of the armature to be 125 feet per second. so that if d be the external diameter of the ring, $\frac{220\,\pi\,d}{60} = 125$ so $\pi\,d = 10.86$.

Phonoplex calculations.

Let λ be the inductance of a coil in a simple circuit containing the coil, an e.m.f. E and a total res. r. the source which is supposed to have no resistance is instantly withdrawn by being short circuited.

Then $+\lambda\frac{dc}{dt} + cr = 0$

$\psi\ \frac{\lambda}{r} = T$ $\quad +T\frac{dc}{dt} + c = 0$

$$\frac{dc}{dt} = -\frac{c}{T}$$

$$\frac{dc}{c} = -\frac{dt}{T}$$

$$\log_\varepsilon c = -\frac{t}{T} + k$$

When $t=0$ $c = C$ $\quad \log_\varepsilon C = k$

$$\therefore \log_\varepsilon \frac{c}{C} = -\frac{t}{T}$$

$$\frac{c}{C} = \varepsilon^{-\frac{t}{T}}$$

$$c = C\varepsilon^{-\frac{t}{T}}$$

$$\frac{dc}{dt} = -\frac{C}{T}\varepsilon^{-\frac{t}{T}}$$

counter emf. $\lambda\frac{dc}{dt} = -\frac{\lambda}{T}C\varepsilon^{-\frac{t}{T}}$

$$= -\frac{\lambda r}{\lambda T}\frac{E}{r}\varepsilon^{-\frac{t}{T}}$$

$$= -\frac{E}{r}\varepsilon^{-\frac{t}{T}}$$

So that in such a simple circuit the numerical value of the extra current e.m.f. commences with the permanent potential difference on the coil and falls logarithmically. consequently the current commences in like manner at the initial value $\frac{E}{r}$ and falls logarithmically.

$$c = \frac{dq}{dt} = C\varepsilon^{-\frac{t}{T}}$$

$$dq = C\varepsilon^{-\frac{t}{T}}dt$$

Total discharge $\left\{ \begin{aligned} Q &= C\int\varepsilon^{-\frac{t}{T}}dt \\ &= CT\varepsilon^{0} = CT \\ &= \frac{ET}{r} = \frac{E\lambda}{r^2} \end{aligned} \right.$

that is to say the total discharge is equal to the amount of electricity that flows in the permanent state through the circuit during the period of time T called the time constant.

At any moment the emf. of discharge is

$$\eta = \frac{\lambda}{T}C\varepsilon^{-\frac{t}{T}}$$

and the quantity dq discharged $dq = C\varepsilon^{-\frac{t}{T}}dt$

$$\therefore dE = \eta\,dq = \frac{\lambda}{T}C^2\varepsilon^{-\frac{2t}{T}}dt$$

Total energy of discharge. $\left\{ \begin{aligned} \therefore E &= \frac{\lambda}{T}C^2\int_0^\infty \varepsilon^{-\frac{2t}{T}}dt \\ &= \frac{\lambda C^2}{2} = EC\frac{T}{2} \end{aligned} \right.$

that is to say the total electromagnetic momentum of the coil is half the energy developed in the permanent state throughout the circuit during the interval called the time constant.

Calculation of size of copper wire for rail connections on car track.

a. rail has say 2 sq. in. of ~~cross~~ cross section = 2.55 m. c. mils.
the equivalent in copper being say $\frac{1}{5}$ R = 364,000 c. mils
a no 10 B&S wire 0.1324" has 18,000 c. mils.
= 20 wires

20 wires in all would be 10 wires (there and back) on each side. The fishplates being 1.5' long the wires would be 2' or cut in lengths of 4'. So that each joint would take 40' of #10 B&S. The track is 2750 feet long making 92 joints lengths in each rail = 184 lengths in all say 190 x 40 = 7600 feet of #10. @ 0.05244 = 413.5 lbs @ 20 cts = $82.

On the density of current on a large steel steam ship's hull supplied by 20 HP

For continuation see page 120

20 HP. = 15 kwt. and 5 volts = $\frac{15000}{5}$ = 3000 amperes.

A vessel 500 feet long and drawing 25 feet of water might for rough purposes be supposed to have the exact shape of an equilateral triangle in immersed section. The slant sides would be about 30 feet in breadth = 1.0 sq. feet per foot of length = 36 000 sq. feet = 1 ampere per 12 sq. feet. = 1 ampere per 11,200 sq. (roughly) 1 ampere per sq. metre.

2 Mr. Noyes took two strips of steel 0.012" thick (0.03 cm) 3" (7.6 cm) wide and 8" (20 cm) long. Shellacked one side of these and immersed them each upright in a jar of salt water :— a fantastic photographic cell with tap water containing NaCl in solution to imitate sea water. sp. g. 1.03 @ 16°C.

One jar with the strip immersed was set aside the other had the strip connected with the Zn pole of two small Bunsen cells, a steel rod forming the opposite electrode. A res. of about 200 ω maintained the current at 0.015 amp. which is approximately equivalent to 1 ampere per sq. foot-metre. Current started at 15 Volts. Bubbles of hydrogen visible on surface of steel.

On the effectiveness of Phonoplex induction coils.

Before discharge an e.m.f. E is maintained at the coil terminals producing a steady flow $\frac{E}{R} = C$. On instantaneously interrupting the battery cct., supposing that possible, this flow C will fall to a value c_1 common to the entire line cct. The time required to effect this is the small interval δt needed by the time of force to withdraw into the coil axis and vanish. All causes that increase the magnetic lag or set up eddy currents in the coil or core tend to prolong δt. At the close of the period the e.m.f. in the coil had risen to $\lambda(C - c_1)$ and the applied e.m.f. from the line assuming $\frac{dc}{dt}$ negligible retardation is $L c_1$. The effective e.m.f. at that moment would thus be $\frac{\lambda C - c_1(\lambda + L)}{\delta t}$ and this must = $c_1 R$ where R is the total res: in cct.

$$\therefore c_1 = \frac{\lambda C}{\lambda + L + R\delta t}$$

To a first approximation therefore, provided that the quality and form of coil ~~core~~ remains R constant, the value of a coil depends upon λC or $E\frac{\lambda}{R}$ or ET, or $\frac{E}{\rho + b}\lambda = \frac{E\,l}{\rho + b}$ where b is the res: of the battery. In other words upon the e.m.f. and time constant of the changing cct.

On the number of turns and size of wire necessary for the series winding in the car transformer field magnets.

The diameter of the core 7⅛" = 7.375", and over lapes say 7.125". a circumference of 23.14", and over the winding the diam: is 10.25" say in this instance 10.5" a circumference of 32.0", under lape say 32.6 the mean circumference being ½ (32.6 + 23.14) = 28". The normal exciting power is about 8000 ampere-turns, and some 1000 ampere turns might be taken as exciting power off the high volt circuit. The current being 12 amperes at full load = 8⅔ turns say 100, or 50 on each limb. 100 turns = 2800" = 233 ft. the energy lost at full load should not exceed 50 Watts = $\frac{50}{100}$ = = 0.35 w = 0.35 w per foot = 0.0015 w per foot = # 14 B.W.G. wire 0.088" = 0.095" circut. = # $\frac{233}{12}$ wire high + 12# deep = 1.114" deep and 0.38" high perhaps with lape 1.25" deep and 0.5" high.

Test of the armature of the No. 4 car transformer on completion Dec: 7th.

Diameter of armature over wire — over bare wire
Resistance of coarse wire set ϕ brush to brush about 0.03 ω
- - fine - - - - - - 5.3 ω
Insulation resistance between sets and to base o.k.
Res: of each section of fine wire 0.195 ω (shunted by all other sections).
One section found to have irregular res: probably imperfect soldering.

Test of the No. 4 transformer with above armature on completion. December 8th

First started machine with 100 volts on primary sec: per and 11 amperes separately supplied to fields. Compound coil out of circuit. Speed 180 revs: per min:
At 1 o'clock Ran machine from municipal dynamo with 21 volts on secondary (o/pins) 21×50 # 1×5 = 1055 volts on primary 0.6 amperes and 12.5 amperes in field separately excited. Compound coil out of cct. Speed 1760 revs: per min. No sparking. Pressure on field 24 volts. Ran for about 15 min: No sparking, some but little vibration and no evidence of undue heating.
20.50 Succeeded after several trials in making transform: start and self excite from rest. P.D. on secondary terminals (o/pins) 21 volts on primary (calculated) 1055 current 0.95 amperes = 1002 Watts. (400 utilised in fields) speed 1900 revs: per min. Running well.
22.20 Stopped running. Bearings blood warm. Put thermometer on armature under wires. Highest temp: 110°F = 42°C. Temp: of air about 70°F = 21°C.

Recalibration of Alternating Current Ammeter for Messrs Bergmann & Co. Dec. 8th.

Speed of Dynamo 2045 revs. per min: driven by belt from flywheel of #2 engine. = $\frac{2045}{60} \times 8$ = 286 alternations = 143 periods per second. The cardew voltmeter was calibrated from the continuous current and then used with the alternating current using various measured resistances of bare platinoid wire stretched up and down the laboratory. The readings were from 0 up to 1.6 amperes and did not differ greatly from those obtained in the previous calibration as recorded in the last Record-Book. The resistance of the instrument was observed to be 1.94 ω @ 20°C and its inductance to vary between 0.003 quadrant with the pointer at zero, and 0.807 quadrants at 1.6 amperes. (2.01 ω w/o 15'.4307)

Test of a specimen of Insulating material for Messrs Bergmann & Co.

Substance resembling hard rubber in appearance, but perhaps moulded with aid of glue from rubber crushed. Soft. Would not take polish. Would not take thread or turn in the lathe. Soluble in water. KHO 10%. NH_4HO, vinegar, alcohol vs. Blisters and cracks under severe heat. Does not nourish flame. Sp. g: 1.36. Swells when soaked in water. Very soft and easily filed. Will perhaps serve for some mechanical purposes where strength is not needed.

Installation of Storage Battery for Pennsylvania R.R. Co. at Philadelphia

105 cells @ 0.75 volt = 79 volts + 2.6 ω @ 0.025 ω each

70 cells @ 0.75 volt.
= 52.5 volts + 1.75 ω
@ 0.025 ω each.
300 amp. hrs

Whole battery 175 volts @ 0.75 volt
= 130 volts @ 0.025 ω
= 4.4 ω

Delivering 7 × 0.033 = 0.233 amp.
= 5.6 amp hrs daily
= 27 days work.
@ 150 amp hrs.

Line	Volts	Wd. ω	C.					
P.R.R. #13	52.5	17500	0.033	37	7800 ω	110	N.Y. #12	240 ω 7830 ω
P.R.R. #15	52.5	1760	0.033		4730 ω	320	P.R.R. #2	160 4775
Ky. #7	162.5	6030	0.027	37	5590 ω	110	P.R.R. #1	200 6000
P.R.R. #18	52.5	1750	0.030	180 ω 37	4220	320	P.S.U. #1	210 6270
P.S.U. #2	132.5	4650	0.030	37	10500	320	N.Y. #13	160 4770
P.R.R. #14	72.5	2210	0.033	1900 ω	4270	320	P.R.R. #9	210 6300
P.R.R. #24	52.5	1590	0.033	37	4090	320	P.R.R. #21	162 4840

35 cells @ 0.75 volt
= 26 volts + 0.75 ω
@ 0.025 ω.

delivering 0.2 amp hr
= 4.8 amp hrs daily
= 6½ days at work
for 300 amp hrs

	P.R.R. #23	26 ω	950 ω 0.025
110	Mny. #2.	136	3225 0.038
	P.R.R. #22	26	975 0.025
	H.E. Line	26	980 0.025
	P.R.R. #12	26	1020 0.025
	P.R.R. #19	26	1020 0.025
	P.R.R. #4	26	1030 0.025
	P.R.R. #20	26	990 0.025

Total equipment 105 cells of 150 amp hrs.
105 - - 300 - -
7200 ω of resistances.

Note

Traction Calculations.

Let m be the mass of the car complete with material and personnel.
n . . . . . passengers.
μ . . coefficient of friction.
v . . velocity of the car (assumed uniform).
p . . pull delivered at the axles
θ . . gradient.

Then the pressure of the ~~f~~ loaded car on the track is in lbs $g(m+n)$, and the pull exerted is expressed by the equation

$$p = \mu g(m+n) + g(m+n)\sin\theta$$
$$= g(m+n)(\mu + \sin\theta)$$

so that the rate of doing work is

$$w = pv = gv(m+n)(\mu + \sin\theta) \text{ ergs per second.}$$

and expressed in watts this becomes

$$W = gv(m+n)(\mu + \sin\theta)\,10^{-7} \text{ watts}$$

$g = 981$
μ varies between 0.0056 and 0.0089 for locomotive rails
0.0125 . 0.025 . streets .

m = 5500 lbs say = 3,850,000 = 3.85×10^6
n = 30 passengers @ 1155 lbs say . 4350 lbs = 1.97×10^6 } $m+n = 5.8 \times 10^6$
7 miles per hour = 313 cms per sec. = v
for $\theta = 0$ $W = 0.981 \times 10^3 \times 3.13 \times 10^2 \times 5.8 \times 10^6 \times 2.0 \times 10^{-2} \times 10^{-7}$
$= 3.7642 \times 10^3$
$= 3.76$ kwts loaded.

The highest gradient on the routes is 0.04 in which case the loaded car at 7 miles per hour will take at its axles 10.7 kwts.

Car running Empty					Car loaded with 30 passengers				
Miles per hr.	Level kwts.	1% kwts	2% kwts	4% kwts	Miles per hr.	Level kwts	1% grade kwts	2% kwts	4% kwts
1	0.34	0.51	0.68	1.02	1	0.51	0.77	1.02	1.54
3	1.02	1.53	2.04	3.06	3	1.53	2.30	3.06	4.60
5	1.69	2.54	3.38	5.08	5	2.55	3.82	5.10	7.64
7	2.37	3.56	4.74	7.12	7	3.57	5.36	7.14	10.72
10	3.38	5.07	6.76	10.14	10	5.09	7.64	10.18	15.28

For the direct pull of starting,

$$p = g(m+n)(\mu + \sin\theta)$$

in cgs $= 981\,(5.8)\,10^6\,(2.0)\,10^{-2}$
$= 11.6 \times 0.981 \times 10^7 = 11.38 \times 10^7$
$= 1138$ megadynes
$= 11.6 \times 10^{10}$ } on level
$= 116$ kgms.
for 10% grade $= 981\,(5.8)\,10^6\,(12.0)\,10^{-2}$
$= 682$ megadynes
$= 69.6 \times 10^{10}$ } on 10% grade
$= 696$ kgms

$p = (m+n)(\mu + \sin\theta)$
$= 12{,}850\,(0.02)$
$= 257$ lbs on level
$= 12{,}850\,(0.07)$
$= 899.50$ lbs on 5% grade
$= 900$ lbs fair max.

Total rainfall for month of

January = 5.04"
February = 2.21"
March = 2.91"
April = 6.36"
May = 3.00"
June = 1.86"
July = 15.25"
August = 4.31"
September = 11.54"
October = 2.56"
November = 13.25"
December = 2.99"
Total rainfall for the year 1889 = 71.28 inches

Meteorologicae report to Bureau department. W. S. Rosenmuller.

Highest Winter Temp. 56° Jan 17th 1889, 63° Jan 12th & 21st 1890
Lowest " 13° Feb 23rd 1889, 20° Jan. 22nd 1890
Mean annual Temp. 56°
Average annual rainfall, 71.28 inches for 1889.

Meteorological record.

Continued from p. 62

Date	Time	Barometer readings Inches	Cm	Temp.	Corrected 0°C	Thermometer Max	Min	Dry	Wet	Rainfall 24 hours	Wind	Remarks.
1889												
Dec. 14		30.032	76.29	66°	29.930	41°	26°	29°	—	Snow	NE	Overcast
15		29.912	75.98	54°	29.846	42°	24°	40°	34°	—	NE	Fine
16	Noon	29.948	76.07	71°	29.881	48°	21°	46°	42°	—	NE	Fine
17		30.028	76.27	70°	29.914	49°	38°	45°	45°		NE	Overcast
18		29.968	76.11	68°	29.260	54°	31°	53°	51°	0.48	NE	Overcast
19		29.750	75.56	70°	29.624	56°	36°	50°	48°	0.25	NE	Fine
20		29.710	75.46	70°	29.586	53°	36°	48°	47°	0.01	SW	Overcast, Rain
21		30.120	76.50	74°	29.982	50°	24°	46°	43°	—	W	Fine
22		29.934	76.05	74°	29.862	48°	34°	39°	36°	—	W	Fine
23	Noon	29.854	75.79	72°	29.796					0.89		Rainy, overcast
24		29.752	75.57	70°	29.688					0.24	SW	Rain
25		29.716	75.47	68°	29.608						SW	Fine
26		29.762	75.59	73°	29.639	65°	42°	42°	41°	0.74	NE	Overcast, thunder
27		29.710	75.48	70°	29.580	53°	38°	36	34°		NE	Fine, storm
28	12 —	29.800	75.81	76°	29.718	54°	30°	43°	43°	—	W	Fine
29	11.30	29.962	76.11	62°	29.092	45°	30°	38°	34°	—	W	Overcast
30		30.136	76.55	70°	30.032	51°	30°	40°	39°	—	N	Overcast, showy
31		30.024	76.26	74°	29.898	50°	28°	41°	39°	—	NW	Fair
1890												
Jan. 1						60°	31°	39°	39°		SE	Overcast
2		30.104	76.47	73°	30.061	64°	37°	49°	48°	0.03	W	Overcast
3		30.430	77.30	76°	30.298	62°	34°	44	40	—	NW	Fine
4		30.420	77.27	72°	30.295	46°	26°	30°	30°	—	N	Fine
5		29.750	75.56	60°	29.666	55°	45°	38°	38°	—	W	Fine
6	Noon	29.892	75.93	67°	29.792	55°	32°	45°	44°	—	SW	Overcast.
7		29.900	75.92	69°	29.962	59°	26°	46°	47°	—	W	Fine
8		29.602	75.20	79°	29.461	59°	49°	48°	47°	—	W	Fine
9		29.574	75.13	78°	29.464	46°	36°	30°	29°	—	NW	Fine
10		29.572	75.17	78°	29.638	48°	32°	36°	34°	—	W	Fine
11		29.364	74.62	75°	29.835	58°	36°	53	52°	—	NW	Overcast
12		29.938	76.05	68°	29.850	60°	35°	48°	40°	—	W	Overcast
13	Noon	29.530	75.03	79°	29.387	65°	37°	45°	44°	—	W	Overcast with
14		30.026	76.24	76°	29.244	46°	36°	42°	38°	—	NW	Fine
15		30.010	76.24	76°	29.900	60°	35°	49°	40°	1.50	NW	Fine
16		29.612	75.25	74°	29.538	60°	35°	44°	41°	0.37	SW	Overcast showy
17		29.570	75.04	70°	29.538	54°	35°	44°				
18		30.246	76.77	70°	30.122	43°	27°	34°	33°	—	N	Fine
19		30.200	76.70	60°	30.092	38°	24°	36°	—	—	W	Fine
20		29.600	75.20	70°	29.472	48°	29°	40°	—	0.16	E	Fine
21	Noon	29.950	75.89	73°	29.737	69°	31°	52°	48°	[illegible]	SW	Fine, overcast
22		30.180	76.62	62°	30.000	60°	35°	50°	—	[illegible]	W	Fine
23		30.228	76.78	66°	30.150	55°	25°	50°	—	[illegible]	W	Fine
24		29.830	76.00	69°	29.693	55°	29°	35°	—	—	NW	Overcast
25		29.744	75.58	72°	29.494	59°	29°	38°	0.03	0.02	W	Overcast
26		29.990	76.13	73°	29.867	43°	30°	36°	—	0.16	W	Overcast, fair
27		29.264	74.37	70°	30.150	47°	36°	36°	33°	0.00	NW	Fine
28		30.124	76.51	72°	30.007	57°	33°	44°	41°	.92	SW	Fine
29		30.022	76.27	76°	29.916	57°	37°	45°	—	—	NE	Fine
30		30.122	76.53	76°	29.990	46°	35°	39°	—	—	S.E.	Overcast Fair
31												
Feb. 1		30.292	76.92	77°	30.157	43°	39°	40°	—	—	W.	Overcast. Fair
2		30.224	76.72	63°	30.091	46°	28°	37°	—	.11	S. W.	Rainy
3		29.890	75.93	75°	29.761	47°	32°	41°	—	—	W.	Overcast
4		30.010	76.24	78	29.832	50°	39°	42°	—	.42	W.	Overcast Rainy
5												
6												
7		30.351	77.20	58°	30.233	60°	17°	26°	—	—		Overcast Fair
8		29.453	74.80	78°	29.316	59°	26°	51°	—	.15	W.	Overcast Rainy.
9		30.335	77.06	68°	30.294	52°	21°	27°	—	.44	S. W.	Fair
10											W.	Overcast Fair
11		30.340	77.09	70°	30.221	32°	25°	25°	—	—	S. W.	Fair
12		29.940	75.98	75°	29.781	49°	38°	44°	—	—	S. W.	Fair
13		30.087	76.36	76°	29.917	47°	22°	40°	—	—	W. C.	Overcast Fair
14		29.655	75.41	76°	29.531	46°	32°	45°	—	—		
15		29.776	75.69	75°	29.581	51°	46°	45°	—	.68	W.	Overcast Rainy
16		30.300	76.95	65°	30.203	46°	26°	31°	—	—	S. W.	Fair
17		29.916	76.00	76°	29.816	45°	31°	44°	—	—	S.	Fair
18		29.553	75.14	78°	29.415	60°	39°	55°	—	—	S. W.	Fair
19		29.728	75.02	76°	29.676	68°	32°	57°	—	—	W	Fair
20		29.408	74.71	75°	29.279	41°	31°	40°	—	.73	W	Rainy, Rain, Snow
21		29.854	75.88	66°	29.732	48°	18°	25°	—	—	W	Fair
22		29.876	75.88	53		34	20	32				
23		29.850	75.83	70		30	20	35				
24		29.840	75.80	72	29.720	44°	22°	40°	—	.11	S. E.	Cloudy Rainy
25		29.804	75.71	74°	29.678	46°	40°	43°	—	.10	N. E.	Cloudy
26		29.703	75.45	79°	29.562	60°	43°	63°	—	.05	N. E.	Fair
27		30.000	76.20	77°	29.865	63°	39°	47°	—	—	N E	Fair
28		29.757	75.62	76°	29.625	54°	37°	43°	—	.44	N. E	Rainy.

Measurement of the effect of tinning a copper wire upon its resistance, for The Edison Machine Works.

Two lengths of wire # 19 B&S soft copper were received from Schenectady; each was about 600 cms long but one was tinned while the other was in its natural condition. These wires were carefully uncoiled to avoid twists or stresses and were laid parallel along the floor. One end of each was fastened down, and the opposite free ends were kept fairly tight by a weight of some 2900 grammes applied by a wire running over two pulleys. The two tested wires were thus parallel, almost horizontal and about 3 cms apart. A current from 2 nitro-chromic cells was sent through them in series and brass knife edges beneath them placed adjustable portions of their lengths in connection with the differential galvanometer. By means of a micrometer screw gauge the diameters of these wires were observed as follow:—

No. of obs.	Diam. of Tinned wire in inches	Δt $\times 10^{-4}$	v^2 $\times 10^{-8}$	$\frac{4\Delta t \sqrt{v^2}}{\sqrt{n(n-1)}}$	Probable Diam. in cms	No. of obs.	Diam. of untinned wire in inches	v	v^2	$\frac{0.67\Delta t \sqrt{v^2}}{\sqrt{n(n-1)}}$	Probable diam. in cms.
1	0.0415	9	81	5.51×10^{-4}		1	0.0422	1	1	3.75×10^{-5}	
2	25	1	1	Result		2	22	1	1	Result	
3	26	2	4	0.0412.1109 ± 0.000055	0.10775 ± 0.00014	3	22	1	1	0.0412.104 ± 0.000038	0.10697 ± 0.00010
4	22	2	4			4	23	2	4		
5	20	4	16			5	18	3	9		
6	25	1	1			6	20	1	1		
7	23	1	1			7	21	0			
8	34	10	100			8	22	1	1		
9	26	2	4			9	22	1	1		
10	23	1	1			10	22	1	1		
11	26	2	4			11	17	4	16		
12	23	1	1			12	22	1	1		
13	22	2	4			13	16	5	25		
14	22	2	4			14	23	2	4		
15	25	1	1			15	23	2	4		
16	22	2	4			16	16	5	25		
17	32	8	64			17	19	2	4		
18	22	2	4			18	21	0			
19	24	0				19	23	2	4		
20	25	1	1			20	22	1	1		
21	21	3	9			21	28	7	49		
22	25	1	1			22	21	0			
23	26	2	4			23	19	2	4		
	594		Σv^2 314				484		Σv^2 157		
Mean	0.0412 499		$\sqrt{\ } = 177 \times 10^{-4}$ $\frac{177}{5.74 \times 10^{-4}}$				0.0412.104		$\sqrt{\ } = 1.25 \times 10^{-4}$		

The difference in diameter is thus 0.00079 cms or a mean tinning thickness of 0.00039 cm. Ratio of diameter 1.0075. If the layer of tin had the conductivity of copper the conductance of these two wires would be in the ratio of 1.015 nearly, or would differ by about 1½ %, owing however to the inferior conductivity of tin, the difference is decidedly less.

No.	Length untinned	Length tinned	Difference	Ratio		No.	Length untinned	Length tinned	Difference	Ratio	Mean Ratio
1	595.4	600	4.6	1.0078		6	352.7	353.7	1.0	1.0030	
2	532.4	535	2.6	1.0049		7	294.5	295.5	1.0	1.0035	
3	494.5	498	3.5	1.0071		8	237.7	238.3	0.6	1.0027	
4	453.1	456.5	3.4	1.0077		9	182.0	182.5	0.5	1.0028	
5	400.3	403.7	3.4	1.0088		10	593.4	597	3.6	1.0060	1.0054

log 0·1069742 0·0028
0·0534425 5·7282320
5·4561640
π 0·4971509
3·9536129 0·008987

Table of tinned copper wires.

Diam. of wire inches	Thickness of tinning in inches or $\frac{d}{2}$					
	0·00005" %	0·00010" %	0·00015" %	0·00020" %	0·00025" %	0·00030" %
0·010	1·5	3·0	4·5	6·0	7·5	9·0
0·020	0·75	1·5	2·3	3·0	3·8	4·5
0·030	0·5	1·0	1·5	2·0	2·5	3·0
0·040	0·4	0·8	1·1	1·5	1·9	2·25
0·050	0·3	0·6	0·9	1·2	1·5	1·8
0·060	0·25	0·5	0·75	1·0	1·25	1·5
0·070	0·2	0·4	0·6	0·9	1·1	1·3
0·080	0·2	0·4	0·6	0·8	0·9	1·1
0·090	0·2	0·3	0·5	0·7	0·8	0·9
0·100	0·15	0·3	0·45	0·6	0·75	0·8
0·110	0·1	0·3	0·4	0·5	0·7	0·85
0·120	0·1	0·15	0·4	0·5	0·6	0·75
0·130	0·1	0·2	0·3	0·4	0·5	0·7
0·140	0·1	0·2	0·3	0·4	0·5	0·65
0·150	0·1	0·2	0·3	0·4	0·5	0·6
0·160	0·1	0·2	0·3	0·4	0·5	0·55
0·170	0·1	0·2	0·3	0·4	0·4	0·5
0·180		0·2	0·25	0·3	0·4	0·5
0·190		0·2	0·25	0·3	0·4	0·5
0·200		0·15	0·2	0·3	0·4	0·45
0·210		0·1	0·2	0·3	0·35	0·4
0·220		0·1	0·2	0·3	0·35	0·4
0·230		0·1	0·2	0·3	0·35	0·4
0·240		0·1	0·2	0·25	0·30	0·4
0·250		0·1	0·2	0·25	0·30	0·35

Working formula for centimetres

$$x = \frac{100\,t\,\{d(n-2) + t(n-1)\}}{nr^2 + 2rt}$$

$$= 100\frac{t}{r}\left\{\frac{6d + 7t}{8r + 2t}\right\}$$

$$= 100\frac{t}{d}\left(\frac{6d + 7t}{2d + t}\right)$$

$$= 50\frac{t}{d^2}\,(6d + 7t)$$

$$= 300\frac{t}{d} \text{ for cms.}$$

$$= 750\frac{t}{d} \text{ for inches}$$

The table gives the effect % of any given thickness of tinning on the conductivity of the wire.

The resistance of 523·2 cms. of the untinned copper wire @ 18°C was found to be equal to the 0·1 Ω std. coil @ 19·2°C. This resistance is correct @ 14°C. 19·2 − 14 = 5·2 × 0·03 = ·156 Ω actual res. would therefore be 0·10016 Ω.
The res. per cm. of wire would be $1{\cdot}91444 \times 10^{-4}$
area being 0·008987 sq. cm. ; its resistivity = $1{\cdot}721 \times 10^{-6}$ Ω @ 18°C.
98 × 0·388 = 6·9824 1·721 ÷ 10·698 = 160 g abs. units
a conductivity of = 100·7 %.

The tinned wire would have a conductivity of

$$\frac{100{\cdot}7 \times 1{\cdot}00544}{1{\cdot}015} = 99{\cdot}7\ \%$$

so that the effect of tinning was apparently to reduce the conductivity one per cent.

Mathematical Theory of the effect.

To find the modification of conductivity in a tinned wire assuming that the wire is a right cylinder and that the tin is deposited cylindrically on its surface while the two metals retain their independent conductivities.

Let r be the radius of the wire (cms)
R " " " " tinned wire
t " " thickness " tinning = $\frac{d}{2}$.

The conductance of the wire alone is $\frac{\pi r^2}{\rho_c}$ per unit length where ρ_c is the resistivity of the copper

The conductance of the layer of tin alone is $\frac{\pi(R^2 - r^2)}{\rho_t}$ per unit length where ρ_t is the resistivity of the tin.

The total conductance is thus $\frac{\pi r^2}{\rho_c} + \frac{\pi(R^2 - r^2)}{\rho_t}$ per unit length

Let $\rho_t = n\rho_c$ then $C = \frac{\pi r^2}{\rho} + \frac{\pi(2r + t)t}{n\rho}$ . . .

$$C = \frac{\pi(nr^2 + 2rt + t^2)}{n\rho} \quad . \quad .$$

The total resistance is thus $= \frac{n\rho}{\pi(nr^2 + 2rt + t^2)}$ . .

The apparent total resistivity is therefore $= \frac{n\rho\{\pi(r+t)^2\}}{\pi(nr^2 + 2rt + t^2)}$ . . .

$$\rho_{app} = \frac{n\rho R^2}{nr^2 + 2rt + t^2}$$

Let x be the apparent percentage loss of conductivity. Then

$$\frac{\rho_{app}}{\rho} = \frac{100 + x}{100} = \frac{nR^2}{nr^2 + 2rt + t^2}$$

$$\therefore x = \frac{100(nr^2 + 2rt + t^2 - nR^2)}{nr^2 + 2rt + t^2}$$

$$= -\frac{100(nr^2 + 2rt + t^2 - nr^2 - 2nrt - nt^2)}{nr^2 + 2rt + t^2}$$

$$= -\frac{100\{2rt(2-n) + t^2(1-n)\}}{nr^2 + 2rt + t^2}$$

$$= \frac{100\,t\{2r(n-2) + t(n-1)\}}{nr^2 + 2rt + t^2}$$

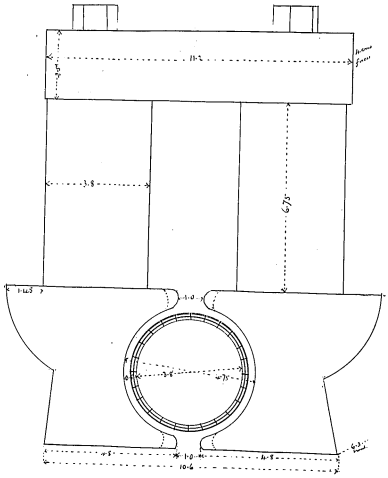
The tabular value of n for tin and copper is 8, so that for the above experimental case having r = 0·0535 and t = 0·00039

$$x = \frac{100 \times 0{\cdot}00039\{0{\cdot}107 \times 6 + 0{\cdot}00039 \times 7\}}{8 \times 0{\cdot}0535 \times 0{\cdot}0535 + 0{\cdot}2 \times 0{\cdot}00039}$$

$$= \frac{0{\cdot}039(0{\cdot}642 + 0{\cdot}0028)}{0{\cdot}0252 + 0{\cdot}0007}$$

$$= \frac{0{\cdot}039 \times 0{\cdot}6448}{0{\cdot}0253}$$

$$= 0{\cdot}99\ \%$$



Weight of field unwound 137 g. 3,880 g.
Diam. of limb $1\frac{1}{2}$" = 3.8
" " armature 1.5" = 3.8
Length " = 2.5 = 6.3

Flux necessary with 1 wire 38 turns round for 500 cms per sec. = 2.16×10^8 = 7250 AT.
" obtained with 10 Watts per sq.cm. 2900.
Reluctance of magnetic cct. 0.032.

Armature
24 divs: 1 wire 38 (but probably) 36 turns round — Armature diam. when wound
2 layers of 114 — 4 layers of 114 = 4.55
Bifilar wire all round 2688 turns. all round
5700
Circumference of armature 38
Size of wire # 32 B.W.G. = 0.009 = .81 c.mil
162 c.mils will allow 0.3 amperes @ 500 c.mils per amp.
= 330 watts = $\frac{1}{13}$ HP.
Res. of armt. 15.8 $\frac{13}{320}$
Fields. wound with # 31 B.W.G. 0.010" silk cond. 23½ oz in all. 11¾ oz each limb
25 layers of 190 turns. for each limb.
Res. of field 1 250 ω each limb = 500 ω total. (cold) current 0.21 amp
Total current 0.5 amp. at full load.

Designed Small Motor of Edison Type

Calculations for its winding.

The diameter of the armature being 3.8 its circumference = 11.94. Out of this there will be 24 teeth each 0.005" = 0.0125 = 0.3. leaving 11.6 or 0.48 to each division. The wire employed on the armature is 0.009" measured say 0.014" covered. $\frac{0.034}{.014}$ = 114 on the first layer, so that 1 wire 38 turns round will give 4 layers. = 0.136 cm + 4 thickness of paper each 0.007 = 0.028" = 0.07 cm = 0.206 cm. thickness of winding = 4.2 cm diameter of armature.

Assuming a peripheral velocity of 1000 ft per min = 500 cms per sec. we have $56 \times 24 \times 37.9 \times \phi = 1.10 \times 10^{10}$ or $\phi = 2.16 \times 10^8$

$5.09 \phi = 1.10 \times 10^9$

The reluctance is $1.0 \times \frac{1}{5.0 \times 6.3}$ = 0.0318 and allowing 20% for leakage or 0.72×10^8 gives the required flux 2.88×10^8

$31.5 \times 1.26\ n = 2.88 \times 10^8 \therefore n = 7.25 \times 10^2 = 7250.$

The diameter of the field after winding will be about 5.5 a circumference of 17.3 and the total length = 13.5 so that the area = 233 sq. cms. Allowing 20 to the watt = 11.7 Watts. @ 110 volts = 0.1 amperes (hot) = 1100 ω (hot) 30°C = 1060 ω @ 20°C. (520 ω each)

Taking the internal diam: as 4 cms and the external as 5.5 the coiling space on each limb is $6 \times 0.785 \times (30.25 - 16) = 4.7 \times 14.25$ = 67 c.c.

$$d = -0.004 + \sqrt{\{(4.0 \times 10^{-3})^2 + 1.53 \times 10^{-3} \sqrt{\tfrac{67}{500}}\}}$$

$$+ 0.00153 \sqrt{0.0268}$$

$$+ 0.00153 \times 0.3556$$

$$0.00016 + 0.00054$$

$$\sqrt{0.000570}$$

$$\sqrt{5.7 \times 10^{-2}}$$

$$= 2.39 \times 10^{-1}$$

$$= 0.024 - 0.004$$

$$= 0.020 \text{ cms.} = 0.008".$$

The mean diam = 4.75 cms = 1.9" and the mean circumference 5.97" say 0.5 feet. There will be about $\frac{2500}{11}$ = 220 turns to the layer = 110 feet and the depth of winding is $\frac{1.5}{2}$ = 0.75 = 0.3" = $\frac{300}{13}$ = 27 layers = 2970 feet × 0.161 ω = 478 ω.

The number of turns will be about 6000 on each limb = 12,000 in all + the number of AT. 1200

Allowing 10 sq. cms per Watt = 23.2 Watts @ 110 volts = 0.21 amperes = 520 ω (hot) = 500 ω say coil on 250 ω on each limb

$$d = -0.004 + \sqrt{\{0.000016 + 0.00153 \sqrt{\tfrac{67}{250}}\}}$$

$$\sqrt{0.268}$$

$$0.52$$

$$0.000796$$

$$\sqrt{0.000812}$$

$$\sqrt{8.12 \times 10^{-4}}$$

$$0.0285 - 0.004$$

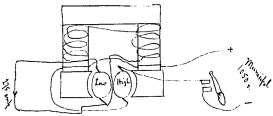
$$0.02485 \div 2.54 = 0.0096" \text{ say } 0.010" = 0.013" \text{ cmd.}$$

$\frac{2500}{13}$ = 190 turns per layer = 59.5 feet. + $\frac{300}{13}$ 23 layers = 2070 feet

Res. per layer = 190 turns in all × 0.21 = 1800 AT in all.
= 210 ω = 4370 turns per limb

Wgt. per ω of this wire # 31 B.W.G. = 0.00293 + 500 ω = 1.465 lbs = 23½ oz = 11¾ each limb

1 turn of the turns = 20 cms say 8" = 9.6" = 0.8' =



Preliminary Measurements of Car Transformer Work.

December 18th Transformer armature #2 ready. Res: of fine wire circuit between brushes 50 @ 20°C.

1st with field excited separately by 100 volts and lamp-bank 20. volts on field terminals

113.5 volts on for: 2·1 volts on secondary 193 revs: per min.

17 o'clock. Machine self exciting and loaded with 275 amperes obtained by employing overhead wires in multiple.

1000 (abt) volts on for 5·5 amperes. 5500 watts Efficiency 80%

16 " " per terminal 275 amperes. 4400 "

18 o'clock Stopped running. Highest temp. indicated by thermometer above armature under waste 127·F.

Description of shock accidentally received in preparing for above test.

The field magnets were separately excited but the series winding were in cct: with the municipal machine, high volt armature. Had stopped the transformer by opening the switch, but had not cut off the pressure from the wires leading from the dynamo. One of these wires connected with a transformer brush had by the movement of the rocker arm been brought in contact at a bare spot with the bed plate so that one terminal of the municipal dynamo was in communication with the framework of the transformer. Was examining a connection between lead, series coil for tightness and held it in the right hand resting on the 3rd phalanx of the middle finger. It was a brass connector. Had rubber galoshes on and did not feel any pressure on this connector. While still holding it must have accidentally touched the framework of the transformer with a knuckle of the left hand. This brought the pressure of 1050 volts upon the body through the two hands. Have no precise knowledge of the manner in which this contact was made nor of the duration of the same, but since the burn on the left hand was just at the outer knuckle of the middle finger between the second and third phalanges, I suppose that the contact was momentary only. The sensation was indescribable. It was a violent rending pain chiefly felt through the whole length of the arm but also ~~slightly~~ in the trunk. I imagined that the current was steadily flowing through me and have distinct recollection of making a voluntary effort to clear myself of the wire. My right hand however remained clutched over the wire it held. The impressions were that I was receiving the current during five seconds or so but this was probably quite a delusion. Under this impression tried hard to shout for help to clear the wires while struggling with that object. Imagined that I was screaming loudly though inarticulately. Was subsequently informed that I had not screamed but only produced gurgling moans, audible however across the engine room among the noise of machinery. Fell slowly over as it has since been described, and as I can distinctly remember on the

right side turning round as I did so under the restraint of the wire grasped in right hand. Fell on right shoulder and back fully over a flump bank, breaking some six or seven lamps. Just about the instant I fell, the pain of the shock left me. Imagined the total time to have been fully five seconds but suppose it was between two and three. In this time many ideas passed through the mind, in particular the consciousness was present that I was getting a high tension shock although it was quite unexpected, and also one or two cases passed through my mind of the further endeavors made by persons receiving heavy shocks to free themselves of connections. Conspicuous was the case read of in the Herald evidence. The moment the pain ceased remember seeing two or three persons hasten forward to my assistance, and recollect their relative approximate positions in the room, they had not moved from their original positions more than a few feet. The next impulse was to free the right hand from the wire it still held. The middle finger was heavily flayed and needed the temporary assistance of the other hand to restore it, when the wire quitted under its own elastic pull. No other ill effect were then felt. Rose to my feet. A rush of perspiration then came to the hands, and I felt that they were slightly scarred. There were blisters on the right hand and a burn deeper than a blister on the knuckle of the left. The mind seemed quite clear and unaffected, but there was some nervousness and an effort was required to prevent the quivering of the under lip. Some sleeplessness was noticed later, and slight nervous pains but nothing of any consequence. There appeared to be a slight difficulty in the first hour afterwards of estimating the weight of any object properly when lifting it in the hand, but this may only have been an imagination. Had no means of knowing the quantity of current that passed through the arms; but although right hand was inside the outside of the left hand would be nearly dry, and therefore the amount was probably very small.

Heating of bobbins for ore milling
Electro magnets by current

The spool described on page gg was subjected for 2 hours to a current of 1.63 amperes its resistance being about 51 ω rising however to about 57 ω = 2.657 × 57 = 151 Watts and the ext. surface is 1065 sq. cms = 7 sq. cms. per Watt. Assisted by convection through the interior this spool in the vertical position became so hot that the hand could just be kept upon it. The surrounding normal temp. was about 25°C.

Another spool was wound as directed on page gg below with 21 w (19½) # 19 SWG s.c. cond. in 18 layers of 120 turns each. With 2.7 amperes through it, the temp. at the surface was to about 50°C. under similar circumstances. The dimensions of the coil are:– ext diam 7" (17.7) int. diam. 5" (12.7) height 7¼" (18½) interflange 7¼" (18.2) Res 28.5 ω – 0.87 = 27.6 ω $\frac{27.6}{27}$ = 1.386 = 100° C increase rise of temp. The ext surface is 18.3 × 3.14 × 18.2 = 1046, and the Watts 201 = 5.23 sq. cms per Watt.

22 lbs. will be wound on these spools instead of 19½. Bringing the heat down to 6.6 sq. cms per Watt.

Tests of Transformer #2.

December 28th 1889.

			Pr.	Sec.
10 o'clock	Commenced running.		7.4 amp.;	18.5v. 300amp 5550w
			Speed 1760	
Noon	stopped.		Highest temp. on armature 70°C.	
13.20	Recommenced		Pr.	Sec.
		light	1050? 1.1 amp 1155 w.	20.5v. 10amp 205w. E 0.18
			Power absorbed in running light 950w	
		Commercial load	1050? 2.4 amp 2520 W.	19.2v. 60amp 1152 w. Ins. 1268 E 0.46
		Load:	1050? 6.8 6834W	17.8v. 275 4895 w Ins. 1935w. E 0.72
17.35	Stopped. Brushes sparking heavily and low volt commutator very hot. Fault in the pressure and contact of brushes. Highest armature temp 75.5°C			

Experiment on the variation in the resistance of iron under magnetic stress.

Upon a strip of wood 7.4 long 7.2 wide and 0.45 thick were wound 80 turns of fine iron wire 0.008" (0.0203) diam., in a width of 5.8 so that the average distance apart was 0.09. The whole strip after winding was dipped in melted paraffine wax. It was then supported between the poles of the large electromagnet in a horizontal position so that the flux would pass along the wire on each side, i.e. the direction of the wire approximately coincided with the direction of the field. The resistance of the wire was then observed by bridge with the current (of about 20 amperes) on and off the magnet. The strength of field was not measured.

With the magnet excited the res. with leads deducted was 31.64 w
" " " disconnected " " " " 31.55 w
Diff 0.09 w.
an increase under mag. stress of 0.285 %

The strip was then set vertical and the poles made to approach until about 0.2 from the strip on each side or about 0.9 from each other. Fiber paper was loosely inserted to keep the strip central. The difference in res. on exciting the magnet under these conditions varied from −1.07% to −0.57% making a mean from 8 observations of 0.92. This reduction was probably due to short-circuiting of the wire under stress, for they could be heard to move under the magnetic influence. The short-circuiting of one pair of wire on one side would produce a difference of about 1%

Measurement made for The Edison Machine Works of the effect of stranding wires on their total conductance.

A strand of seven bare soft copper wires neither bright, nor soiled, six wound helically round the seventh, and each 0·065" = 0·165 diam. was laid upon the floor over a length of 625. Seven similar but unstranded wires were laid near and parallel to it. All were stretched by a cord running over two pulleys to a weight of 40 lbs. (18600), averaging thus 1300 per wire. At the ends wires were led off to the differential galvanometer. The current employed to traverse the stranded and unstranded conductors was about 20 amp. and the deflection on one side of the gal. amounted to some 500 divs.

With the connection points 60 in cms apart on the unstranded wire and 60 in·5 cms apart on the strand the deflection showing extra res: on the unstranded side was 2 divs requiring 10 w to balance $\frac{502}{500} = 1{\cdot}0040$ $\frac{2710}{3700} = 1{\cdot}0038$, a difference of 0·38 %. The weight of the unstranded wire was 810. that of the strand 818·5. The strand diameter was 0·190" = 0·482 and there were just 600 hanks across the axis at one side in the whole length of strand = 100 hanks per wire = 6·0 average distance of one complete revolution i.e. the pitch.

Theory of subject based on the assumption that the wires are tubes of flow i.e. that no current passes from one to another.

Let r be the radius of the unstranded wires (all equal)
p - - pitch of the strand i.e. the distance ~~from~~ measured along the strand axis of one revolution.
θ - - angle of twist, between the strand axis and the orthogonal projection of the axis of an outside wire upon a ~~plane diametral~~ of the strand
l - - length of the strand (axis)
n - - number of twisted wires – usually 6.
m - - - untwisted wires – usually 1.
Then if λ - - length of the untwisted wires in length l of axis
and ρ - - res: of the wires per unit length
c - - conductance - - - - - - $= \frac{1}{\rho}$

we have $\lambda = l \sec\theta$

$$\tan\theta = \frac{\pi r}{p}$$

joint res $R_1 = \dfrac{1}{\dfrac{n}{\rho l \sec\theta} + \dfrac{m}{\rho l}} = \dfrac{1}{\dfrac{n + m\sec\theta}{\rho l \sec\theta}}$

$$= \frac{\rho l \sec\theta}{n + m\sec\theta}$$

But $\sec^2\theta = 1 + \tan^2\theta \quad \therefore \sec\theta = \sqrt{1 + \frac{16\pi^2}{p^2}}$

$$= \sqrt{1 + \frac{4\pi^2 d^2}{p^2}} \quad \text{where } d = \text{diam} = 2r$$

$$= \sqrt{1 + \frac{4\pi^2}{q^2}} \quad \text{where } q = \frac{p}{d}$$

$$\therefore \frac{R_1}{R} = \frac{\rho l \sec\theta}{n + m\sec\theta} \times \frac{m+n}{\rho l}$$

$$= \sec\theta \left(\frac{m+n}{m\sec\theta + n}\right)$$

$$\frac{c_1}{c} = \frac{1}{\sec\theta}\left(\frac{m\sec\theta + n}{m+n}\right)$$

If x be the loss of conductance in

$$x = \frac{100\sec\theta\,(m+n) \mp 100\,n}{\sec\theta\,(m+n)} \quad \text{where } m = 1$$

this becomes $\quad x\,\% = \dfrac{100\,n\,(\sec\theta - 1)}{\sec\theta\,(n+1)}$

$$= 100\,\frac{n}{n+1}\left(1 - \frac{1}{\sec\theta}\right)$$

$$= 100\,\frac{n}{n+1}\left\{1 - \frac{1}{\sqrt{\left(1+\frac{4\pi^2}{9}\right)}}\right\}$$

$$= 100\,\frac{n}{n+1}\left\{1 - \frac{9}{\sqrt{9+4\pi^2}}\right\} = \frac{600}{7}\left\{1 - \frac{1}{\sqrt{\left(1+\frac{4\pi^2}{9}\right)}}\right\}$$

In this case $\quad q = \dfrac{2\cdot36}{0\cdot065} = \dfrac{2360}{65} = 36\cdot34 \qquad q^2 = \dfrac{1321}{1296} \quad \checkmark = 36\cdot89$

$$\frac{0\cdot55}{36\cdot89} \times \frac{600}{7} = \frac{3094}{2989\cdot36} = \frac{330}{258} = 1\cdot28$$

The loss in conductance should have been $1\frac{1}{4}\%$

Concerning the mass of a strand

In length l if w be the weight in grammes per cm. of the wire then

$$nl + nl = W_1$$

$$\therefore\ ml + nl\sec\theta = W_1$$

instrandedness $\quad W = (m+n)\,l$

$$\therefore\ \frac{W_1}{W} = \frac{ml + nl\sec\theta}{ml + nl}$$

where $m = 1$, $n = 6$

$$\frac{W_1}{W} = \frac{1 + 6\sec\theta}{1+6} = \frac{1 + 6\sqrt{1+\frac{4\pi^2}{9}}}{7}$$

$$\frac{100+x}{100} = \frac{1 + 6\sqrt{1+\frac{4\pi^2}{9}}}{7}$$

$$x = \frac{600}{7}\left(\sqrt{1+\frac{4\pi^2}{9}} - 1\right)$$

$$= 1\cdot3$$ practically the same result.

The % loss of conductance in a strand of 7 wire is thus

$$85\cdot7\left(1 - \frac{1}{1+\frac{2\pi^2}{9}}\right)$$

$$= 85\cdot7\left(\frac{2\pi^2}{9}\right) \text{ approx.}$$

$$= \frac{1714}{9} \text{ approximately.}$$

and generally speaking the % loss of conductance is approximately equal to the % excess in weight of the stranded over separate wires per unit length.

(2) That it is possible when the strand is compressed and the component wires are clean, for cross conduction to take place from one wire to another in which case the loss of conductance will be less than the proportionate gain in weight.

Test of # 3 Car Transformer

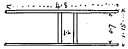
Armature 23. XII. 89

Resistance of a single coil shunted by 95 others 0.017 ω
" " the high tension circuit (brush to brush) 5.85 ω @ 20°C.
Inductance of a single coil shunted by 95 others 0.000160 ω = 1.6 K
" " the high tension circuit (brush to brush) 0.048 ω = 480 K.

The armature was tested lying across wooden horses in air, and its inductance could probably be much greater between the poles of its field magnets. The insulation of the circuits was ok.

Measurement of the change of resistance of iron with magnetisation. Preliminaries could.

A hard rubber spool was taken of the dimensions shown. It was wound with 362 turns of iron wire diam. 0.0105" 0.0266 cond to 0.016" (0.040), in 27 layers averaging 14 turns per layer.



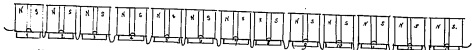
This was supported in ~~approximately~~ two definite positions between the poles 1st with the plane of the coil parallel to the field. 2nd with the plane of the coil at right angles to the field. In the first case conducting the lines of flow to a greater or less extent, the increases of resistance on exciting the magnet was 0.145 ω, 0.155 ω, 0.155 ω, 0.17 ω. Mean 0.155 ω in 12 ω = 0.13 %. In the second case where the coil embraced the lines but only conducted them transversely the effect of exciting the magnet could not be detected, and 0.02 ω or even 0.01 ω could have been noticed.

Determination of the balancing weight for the car motor armature. 30th December. 89

It was ascertained that the weight required to balance the motor armature at 1400 revolutions per min. was

1.75 ounces	at a radius of	6.15" =	10.76 moment
2.3 "	" " "	6.3	14.5
1.0 "	" " "	6.48	6.4
0.25 "	" " "	6.5	1.6
			33.3

If stood in the form of lead poured while liquid into holes at a radius of 3.1" this represents 10.7 oz.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Experiments on the effect of developing hydrogen upon the surface of immersed steel in diminishing rust.

In the preceding experiment (page 103) no decided effect could be observed after some 20 days duration. The experiment was therefore repeated as follows:—

6 gallon jars were filled with tap water containing $NaCl$ in solution (density 1.027 @ 17°C. In the first two plates of steel 0.012" × 0.03") 3.13" (7.9) broad × 8" long (20.3) were immersed. The backs varnished. Similar plates were immersed in the other jars, the rods forming the anodes. The surface exposed in each cell is about 161 sq. cm. of clean steel. (Backs shellacked)

Jar #1	receives a steady current of 0.016 amperes equivalent to	1 amp per sq. metre
" 2	" " " " " 0.032 "	2 amps per sq. metre
" 3	" " " " " 0.048 "	3 " " " "
" 4	" " " " " 0.064 "	4 " " " "
" 5	" " " " " 0.080 "	5 " " " "
" 6	no current	

The current was sustained by 5 separate Bunsen cells.

On the Winding and Testing of the One Milling Magnets described on page 119.

The iron core was wound with 22½ lbs of #8 D.C.C. wire in 4 layers and a half. It was then taped and copper sheeting ⅛" thick laid over it and soldered. A coating of black carpenter's varnish was ~~placed~~ given over all. A current of about 31 amperes was then applied for 3 hours. At the end of that time the hand could be kept on the surface.

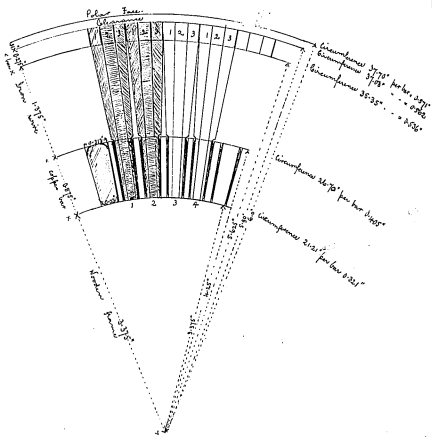
The res. of the magnet + leads was then 0.1608 = 0.1353
Next day after cooling " " " " " 0.1325 = 0.1070
leads 0.0255

The rise of res. was 0.1353 − 0.1070 = 0.0283 = 26.5%
÷ 0.38 = 70°C rise.

The same wire was wound (9.5.90) on a core just twice the length, in 2½ layers.

Particulars of new pattern armature for the ~~Street~~ Bar motor.

The armature made as described on pages 60 and 87 presented considerable difficulty in setting together the larger wires and soldering their ends to the commutator. The design was therefore changed in favour of a bar armature of lower peripheral speed, with brushes on its surface and no separate commutator.



Lower bars to be formed of 7/8" x 5/16 (0.875" x 0.313") bar with rounded edges slots in the ends of these for solder cups 0.5" deep 0.23" wide.

Upper bars to be triple.

Each component strip to be 0.275" high above and 0.5" at sides.

Breadth (plate thickness) 0.162"

Mica between each pair of component bars 0.005" or 0.007 above

" " " " " main " 0.014" beneath or 0.06" above.

Particulars of the Behavior of a Chatillon Steel Spiral Spring under experimental test.

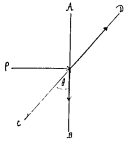
31. 12. 89.

The spring is a single spiral of 3/8" steel wire of 15 turns, its length when all parallel to the axis being 9 3/8" before and after having been closed 9 1/16" (permanent set of 5/16"). The ends are flattened to a plane perpendicular to the axis. The outside diameter of the spiral is 2 7/8", the internal 1 7/8" and the distance separating adjacent spires in relaxed state 1/16". On first compression the following were the observed stresses :—

No. of Exp.	Length of Spring	Compression	Weight suspd.
1	8 2/3	1"·0	190
2	7 7/8	2·0	360·5
3	7 3/8	2·5	452
4	6 7/8	3·0	530
5	6 3/8	3·5	599
6	5 7/8 spires touching	4·0	665

Mathematical Analysis of the Efficiency of Worm Gearing.

It is assumed that the teeth of the worm and worm wheel to engage that sliding friction only is brought into play without bind, i.e. that the teeth are properly shaped + fitted



Let AB be a line parallel to the axis of the worm. Let P be a force applied in the worm's plane of rotation against the teeth of the worm wheel. Let θ be the angle of transmission of the worm, and CD the line representing the pitch surfaces engaged.

Now suppose the force P to advance through a distance d, in doing which the work done will be Pd. The advance of the worm tooth will have necessitated an advance of the worm wheel tooth through a distance $d \cot\theta$ in the wheel plane of rotation and if Q represent the power exerted by the wheel at the pitch line, the work done will be $Q\, d \cot\theta$. The normal stress across the pitch line will be $P\cos\theta$ due to the effect of P diminished by $-Q \sin\theta$ owing to effect of Q so the tangential friction is $\mu(P\cos\theta - Q\sin\theta)$ and the component of d in this direction is $\frac{d}{\sin\theta}$ so that the work done against friction $= \frac{\mu d}{\sin\theta}(P\cos\theta - Q\sin\theta)$

Hence $Pd = Q\, d \cot\theta + \frac{\mu d}{\sin\theta}(P\cos\theta + Q\sin\theta)$

or $P(1 - \mu\cot\theta) = Q(\cot\theta - \mu)$

$$\frac{P}{Q} = \frac{1 + \mu\tan\theta}{\tan\theta - \mu} \qquad \text{Taking } \mu = \tan\varphi$$

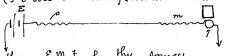
$$= \frac{\cos\theta\cos\varphi + \sin\theta\sin\varphi}{\sin\theta\cos\varphi - \cos\theta\sin\varphi} = \cot(\theta - \varphi)$$

Experiments with the Phonograph Motor for the purpose of driving a sewing machine 1st–5th Jany. 20.

Used a small Singer sewing machine with the treadle disconnected, driving from an ordinary phonograph motor with an extra large pulley on its shaft directly by a round belt to the sewing machine shaft pulley. The velocity ratio was about 2. — 8 Phonograph Nº 140 cells.

No	Revs. per min Armature	Revs. per min Singer	Density	Obserb.	Amperes	P.D. at Motor terminals	P.D. at battery terminals	EMF of batty. cells	Approx. EMF of motor	Power generated in armature	Lost Watts in battery	Lost Watts in motor	η
1	240	480	Running off	1·3	6·67	2·5	3·1	6	1·03	41	23·3	9·8	
2	325	650	" "	1·35	6·92	2·85	3·22	"	1·08	41·5	21·8	12·3	
3	0	0	hold	1·76	9·03	2·0	"	6	0	54	"		
4	314	628	light	1·3	6·67	3·0				40			
5	192	384	working off	1·55	7·95	2·5			"	47·7			
6	282	564	" off	1·4	7·18	2·75				43·1			
			Res: of	battery	0·435	= 0·054	per cell		Res. leads 0·09 in (1) + 0·056 in rest + motor (joint) 0·22				

But separately exciting the magnets from the 110 volt circuit ascertained that up to 2·18 amperes in the field the speed increased, so that at this point (3·6 volts at motor terminals the efficiency should be 0·50)



Let E = the E.M.F. of the source
ρ = res. " " " " leads
m = " " " " motor
η = e.m.f. " " armature.
c = working current
f = effective forces due to magnetic mechanical frictional work referred to the periphery of the armature
r = radius of armature
n = revolutions per min:
ϕ = Total flux magnetically traversing armature.
N = Number of wires all round sector. ($\frac{1}{12}$ circle)

Then $\frac{E-\eta}{m+\rho} = c$ and $\eta c = 2\pi n r f$ and $\eta = \phi N n 10^{-8}$

From these eliminating c

$$n = \frac{E\phi N 10^{-8} - (m+\rho)2\pi r f}{\phi^2 N^2 10^{-16}}$$

$$\frac{dn}{df} = -\frac{E}{\phi^2 N 10^{-8}} + \frac{2(m+\rho)2\pi r f}{\phi^2 N^2 10^{-16}}$$

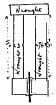
for max: $\frac{E}{\phi^2 N 10^{-8}} = \frac{4\pi r f (m+\rho)}{\phi^2 N^2 10^{-16}}$

or $c = \frac{1}{2}\frac{E}{(m+\rho)}$

$\therefore \eta = \frac{E}{2}$

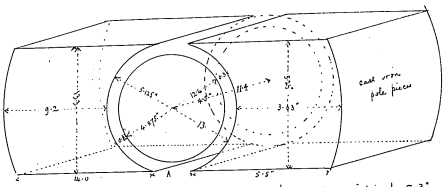
So that for separately excited field magnets the speed of rotation of the motor armature will be a maximum when all other conditions remaining constant the counter emf is just half the source EMF and or when the efficiency is 0·5 and the work done a maximum.

When wound the fields had 9½ layers of 355 turns = 3400 turns.



When complete the field measured 1920 (both coils in series) @ 20°C.
" armature " 1.4400

Speed 2830 revs per min. @ 110 volts p.d. = 2770 ft per min. = 1890 r.p.m.
Current in field 0.57 ampere, in armature running light 0.66 ampere.
Watts 65 73 Watts



The bore of the field was increased to admit winding to 5.3" (13.5) and the distance between polar heads 2.2" (5.6) at A.

Field winding
6 lbs # 26 B.W.G. 0.018" in all or 3 lbs. on each limb.
about 11 layers of 300 turns.

Armature winding
30 divisions separated by 0.025" of paper and fiber
1 wire 10 turns round in each division.
300 complete turns of drum. #28 B.W.G. 0.0320" d.c.c.
With paper 0.03" and wire 2 layers 0.14" = 0.19" + 0.1" = 0.29" clearance
This will necessitate boring out the poles to 5.44", and will practically double the reluctance.
1 turn of armature = 1.5" approx. 1 75 × 1.5 = 112.5" @ 0.0043 = 0.485 Ω
say 0.5 Ω.
24.600 c.mils should allow 8 amperes through armature = 800 Watts
absorbed practically 1 H.P.
The weight of wire on armature = 3.80 lb.
The weight of the bores with pole pieces 92 lbs. yoke 50 lb.
Speed less than 2000 ft per min.
Field radiation 20 sq. cms per Watt. 200 w total rad.
Periphery of armature over bands 5.13" (13.1) = 15.92" circum = 1.33'

Loss in armature. 0.5 × 11.4 × 6.2 × 6.2 = 351 c.c.
Hysteresis dissipation rate @ 2830 revs per min = $47.1 \times 2 \times 351 \times 10^{-3}$ Watts = 33

Calculations for the Winding of a Small Motor of Dimensions shown P.D. 100.

This motor though intended to run off the 110-volt circuit will probably be operated with lamps in circuit. The field magnet may be connected however directly. We may assume a velocity of 2000 ft per min (1000 cms. per sec) at 50 volts counter emf and take any lower desired speed by lamp adjustment.

The rel. of the air gap is $0.3/18 \times 11.4 = \frac{0.3}{205.2} = \frac{3.0}{2.05} \times 10^{-3} = 1.47 \times 10^{-3}$

The cross section of the armature is 12.4 × 11.4 = 140 sq. cms. @ 10,000 lines = 1,400,000 lines required and the cross sectional area of the limbs are 45 sq. cms @ 10,000 lines = 450,000. Say 500,000. of these say 30% or 150,000 will be lost by leakage leaving 350,000 for service. A speed of 1000 cms per sec. with a periphery of 12.7π = 40 cms. gives 25 revs per second.

$$\therefore \quad N = \frac{50 \times 10^8}{3.5 \times 10^4 \times 2.5 \times 10^{-3}} = \frac{5.0 \times 10^8}{0.875 \times 10^3} = 572$$

Taking 600 wires all round the circumference + 24 divs = 25 wires to each division, or 30 divisions and 20 wires to each division.
The circumference of the armature is 12.4π = 39.0 cms. 15.3". 30 fibres each 0.025 = 0.75" leaves 14.55". This leaves 0.14555 for the diameter of the covered wire and allowing 0.015" for the total thickness of covering makes 0.130 for the wire. The nearest size smaller than this is # 28 B.W.G. 0.0320". Thus three layers of such wire will not fit into the space between the pole and armature.
If wound for 100 volts there will be 1200 wires all round and 40 wires to each division = 20 wires to each layer = 0.024" overall = 0.0768 covered say # 26 B.W.G. 0.0404" as nearest size = 19.60 c.mils
It remains to determine the field winding.
This may be 0.33" deep = 0.8 cms. The external diam. will then be 9.2 cms. and the annular area $\pi(9.2^2 - 7.8^2) = 26.5$ sq. cms. = 21.6 sq. cms. and the length 27 cms = 58.3 sq. cms. on each limb. The heat radiated may be 20 sq. cms per Watt = 29.6 Watts = 60 Watts in all from both limbs @ 110 volts = 0.55 amperes = 200 w. in all (hot) = 95 w on each limb coil.

$$d = -0.02 + \sqrt{0.00004 + 0.00153\left(\frac{590}{95}\right)}$$

$$0.00153\sqrt{6.10}$$

$$0.00153 \times 2.47$$

$$0.00378 = 3.78 \times 10^{-3} \quad 37.8 \times 10^{-4}$$

$$41.8 \times 10^{-4}$$

$$6.47 \times 10^{-2}$$

$$= -0.02 + 0.065$$

$$= 0.045 \text{ cms} = 0.018" \quad \#24 \text{ B.W.G.}$$

Covered = 0.023" and in 1 layer there will be 300 turns.
In 0.33" there will be 10 layers and the mean circumference $\frac{8.6 \times \pi}{2.54} = 10.17" = 0.85' + 3000$ turns = 2550 feet @ 0.032 Ω = 81.6 Ω.
If # 27 wire be used (0.016" covered to 0.031") there will be 330 turns per layer + 11 layers = 3630 turns = 3085' @ 0.04 = 12 Ω.
24 = 9 Ω @ 0.0208 lbs per Ω = 2.93 lbs can therefore be placed on each limb. = 6 lbs. in all. # 26 B.W.G. This will give 6000 × 0.55 = 3300 A.T. = 4100 exciting m.m.f.

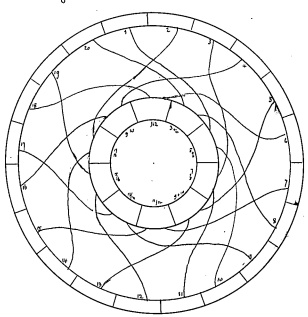
$$\frac{4.100 \times 10^3}{1.47 \times 10^{-3}} = 3 \times 10^6 \text{ lines produced, or considerably beyond saturation}$$

Exp 3rd go. On trial machine gave 110.5 v. @ 2830 revs.

$$\therefore \phi \times 600 \times 47.1 = 1.135 \times 10^{10} \quad \therefore \phi = \frac{1.135 \times 10^{10}}{2.826 \times 10^4} = 402{,}000.$$

6 turns of wire round respect. gave 250 divs of ballistic g. on revs = 110 (for flux thru 5.5,000 0.4064) changed by 1.43 ⁺ (2.40 × 10¹⁰ × 1.43 × 10⁻⁸ = 0.5797 × 10¹⁰ g) produce 62 divs ∴ 1 div = 9.31 × 10⁸ g.
$\phi = 140 \times 10^8 \times 5.53 \times 10^{10} \times 9.31 \times 10^{-8} \times 72.0 \times 10^{-8} \div 6 = 1.201 \times 10^{10} = 1{,}200{,}000$

When rewound as shown the highest temperature shown by thermometer on the armature was 165°F (74°C) after running for one hour though a strong field (excited direct from 135 volt) generating over 8 volts (without brushes).



Particulars of a Test made of the effect of Electrical Endosmose upon the reduction of uric acid calculi in a gouty patient.

16th to 30th Dec. 1889.

The person submitted to this experiment was H. E. Ritter of Moorbleam N.J. aged 73½, who has had an active Gouty Disease was contracted 8 or 10 years ago, and according to patient's statement through sleeping in damp sheets. These calculi commenced at that time & slowly increased until about 4 or 5 months ago when pain commenced apparently from the pressure upon the nerves. There was also noticeable a certain degree of venous congestion in the face attributable to impeded circulation. All the joints except the knees were greatly enlarged by calculi. Thus the girth of the little finger of the left hand was 8.6 cms. and that of the corresponding finger right hand still larger. Great weakness and difficulty in walking. Mind clear and intelligence unimpaired.

Treatment commenced on 16th December with 13 mas. for one hour left hand in $LiCl$ solution density 1.08 up to the ulnar condyle. Right hand immersed in $NaCl$ solution 1.05. Current entered at left hand thus tending to carry $LiCl$ into the tissues. Treatment continued for about four hours daily until 21st Dec. with 20 mas. (110 volts through 90 + galvs.). On that date the measurement of the left hand little finger calculus was 8.2 cms. Treatment continued from 23rd to 24th inclusive. On last day solution exchanged for 1% Li_2O_2 which blistered the hands of the patient in some degree. Patient then discontinued treatment. On 31st Dec. the girth was 8 cms. showing a total reduction of 0.6 cms which was deemed conclusive evidence of beneficial effect. Patient also felt better during treatment the pain in joints ceasing and general amelioration felt by him, that continued journeys to and from laboratory after three years total inactivity had exhausted his strength.

Rewinding of Low Volt Armature.

The great heating of this Z 1000 ampere armature, at very low magnetic densities, apparently owing to foucault current, rendered it necessary to rewind the armature. There are 10 commutator bars and 20 divisions of the armature. In each division were 16 # 9 S.W.G. wire 0.1148" The whole mass had suffered very greatly from overheating. It was rewound with 16 braided # 7 B.W.G. 0.1444 S.C.C. The winding was "side by side" as shown on the opposite page. The diam. of the body over insulating paper is 9¼" (9.7" 246.6 cms.) The length of the body = 10.75" = 27.3. The mean length of one turn will be about 3.5 feet. The effective length of wire on the armature is thus $\frac{3.5 \times 20}{16 \times 10} = \frac{70}{64} = 1.09$ ft

0.0005 ω per ft = 0.000055 ω.

Problem:- To determine the winding of a motor when the work it has to do is stated, and when the magnetic circuit and winding space are outlined

First neglect the field circuit and leave it as a separate consideration

let n be the number of revolutions of the armature per sec:
" w - - - - active wires all round armature (gramme ring)
" φ - the flux $\times 10^{-8}$
" ε - - counter emf of the motor.
" W - - work required from the motor including its own mechanical and electrical friction.
" b - - resistance of the source of emf & its leads
" E - - emf. of the source
" l - - mean length of one turn on the armature (gramme ring)
" K - - total coiling space occupied
" ρ - - mean resistivity of this space
" r - - res: of the armature.
" c - - current strength in the armature.

Then the length of wire round the armature $= wl$

" section of the winding $= \frac{K}{l}$

" section of each wire $= \frac{K}{l} \div 2w = \frac{K}{2wl}$

" resistance of the wire all round $= \frac{2wl\rho}{K}$

" " " " armature " " $= \frac{w^2 l^2 \rho}{2K} = m = \beta w^2$
$= w^2\left(\frac{l\rho}{2K}\right)$ where l = length of winding (gramme ring)

$$\frac{E-e}{b+m} = c \qquad \therefore \frac{c(E-e)}{b+m} = cc = W.$$

$$\therefore \left(\frac{E-\varphi n w}{b+\beta w^2}\right)\varphi n w = W.$$

$$\frac{dW}{dw} = \varphi n\left(\frac{E-\varphi n w}{b+\beta w^2}\right) + \varphi n w\left\{\frac{-\varphi n(b+\beta w^2) - 2\beta w(E-\varphi n w)}{(b+\beta w^2)^2}\right\}$$

for a maximum W with w as independent variable.

$$(E-2\varphi n w)(b+\beta w^2) = 2\beta w(Ew-\varphi n w^2)$$

whence
$$w^2 + 2w\frac{b\varphi n}{E\beta} = \frac{Eb}{E\beta}$$
$$w + \frac{b\varphi n}{E\beta} = \sqrt{\frac{E^2b\beta + b^2\varphi^2 n^2}{E^2\beta^2}}$$
$$w = -\frac{b\varphi n \pm \sqrt{E^2b\beta + b^2\varphi^2 n^2}}{E\beta}$$

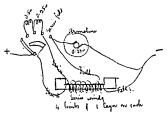
since $b\varphi n$ is usually small in comparison with $E^2b\beta$ we have
$$w = \sqrt{\frac{b}{\beta}} = \sqrt{\frac{b}{\frac{l\rho}{2K}}} = \frac{1}{l}\sqrt{\frac{2Kb}{\rho}} = 2\sqrt{\frac{Kb}{l\rho}}$$

Finally since $\frac{l\rho}{K}$ is the res: the armature would have if all its wires of whatever sizes were in parallel - made one complete turn call this res: R. Then $w = 2\sqrt{\frac{b}{R}}$, and the res: of the armature will then be $\frac{w^2R}{4} = b$.

The current c will then be $\frac{E-e}{2b}$ energy lost in battery $\frac{E^2}{4b} = \frac{E^2}{16b}$ 25%

and for max: work $\frac{E}{2b}$ " " " armature $\frac{E^2}{16b}$ 25%

" maximum work W: $\frac{E^2}{8b}$ 50% " developed $= \frac{E^2}{4b}$



When rewound the armature had a resistance of 0·33 ω
ie: 2 each of 6 turns 0·07 ω
" " " dia: 0·14 ω
as wound, previously. . . . 0·10 ω
present size of armature wire ⌀ 23 B.W.G 0·025"
four layers of 9 turns each = 36 wire per dia.
360 wire per sector.

The fields have 7 layers of 30 turns = 210 turns each.
and the limbs have now a section of 2" × 2" = 1·290 sq. ins.
4·20 turns to each pair of coils.

Still later a series winding has been applied to fields in the armature circuit to help the motor in starting. 1 layer of 30 turns same wire on each limb and all four in parallel = 0·063 ω

Battery 10 double plated cells of R.H.S type.

Machine works satisfactorily.

Application of formulae on preceding page to the determination of the winding of the phonograph motor in sewing machine.

The resistance of battery and leads = 0·45 ω and if the armature be made equal to this the current flowing at maximum work will be $\frac{5.6}{2 \times 0.9} = \frac{6.2}{2} = 3.1$ amperes taking each cells emf. as 0·7 volts. The energy delivered will then be $\frac{5.6 \times 6.2}{2} = 8.68$ watts out of which at least 50% should be utilised after deducting mechanical and electrical frictions. The resistance of the armature is at present 0·25 ω so that it has to be increased to 0·45 ω or as the square root of 1·8 = 1·342 and this represents 80% ~~16 B.W.G~~ c. mils. or ⌀ 23 wire B.W.G. ~~now~~ size smaller than at present. For place of 3 layers of 9 turns there will be 4 layers of 10 turns.

General "Data" connected with winding apparatus.

Having a given winding space κ of resistance r when wound with a certain length l of wire in w turns the diameter of the wire being d its resistivity ρ, the thickness of insulation being t, the supply e.m.f. at terminals E and the current c, then the section of the wire being s the apparent resistivity of the space is

$$\rho_1 = \frac{\kappa r}{l s} = \frac{r(d+2t)^2}{l}$$

but $\rho = \frac{\pi r d^2}{4 l}$

$$\therefore \rho_1 = \rho \frac{4}{\pi}\left(\frac{d+2t}{d}\right)^2 = \frac{4\rho}{\pi}\left(\frac{D}{d}\right)^2 = 1.273\rho\left(\frac{D}{d}\right)^2$$

for pure copper $\rho = 1600 = 2088\left(\frac{D}{d}\right)^2$ @ 0°C.
" 98% " $\rho = 1670 = 2130\left(\frac{D}{d}\right)^2$ @ 0°C.
$= 2200\left(\frac{D}{d}\right)^2$ @ 20°C.

$$r = \frac{w \tau \rho_1}{D^2} \quad \text{where } \tau = \text{mean length of turn}$$

$$\kappa = w \tau D^2$$

$$\therefore r = \frac{\kappa \rho_1}{D^2}$$

$$c = \frac{E D^2}{\kappa \rho_1} \quad \text{Heat}$$

$$f = \frac{E^2 D^2}{\kappa \rho_1} \quad \text{Number of turns}$$

$$w = \frac{\kappa}{\tau D^2}$$

$$cw = \frac{E D^2}{\tau \rho_1} \quad \text{Ampere = turns.}$$

Field winding determination for Sewing Machine Motor

There are about 135 turns of wire on each limb of field = magnet and 1·8 amperes are required to effectively charge field = 243 ampere = turns say 250. To employ only 1 ampere there must be 250 turns ~~but~~ 62 turns on each limb. With maximum work energy the RD on MT should be 0·75 × 5·6 = 4·2 volts. so that the resistance of field must be 4·2 ω in all or 1·05 ω per limb for 250 turns. The mean turn would be about 24 cms long = 0·8" so that 250 turns = 200 ft say 200 ft long. 1000' would thus offer 5·25 ω. = 0·0052 ω per ft = ⌀ 29 B.W.G.

When the armature is at rest the current flowing through it will be 6·2 amperes and 2·8 volts will be at the terminals. This will give only $\frac{250 \times 6.2}{2}$ A.T. to the each pair of fields (333) instead of 500, so that 167 must be supplied by 6·2 amperes = 25 turns = 12 turns on each limb (series winding)

Taking the sp. g. of matte as 5.0, the weight of a plate 3" x 3" x 1" is 235 lbs.

18 sq. feet	thus weigh	235
1 "	— "	13
286,800 "	— "	3,730,000 lbs
		= 1,665 tons.

Each plate occupies say 3" breadth (1" + 2") = 0.25' and 7170 sq. ft in each bath = 398 plates say 400 so that the length of the tank would be 100 ft

The building would be 40 x (3 + 5) = 200 ft long
× 125 = feet

Measurement of the Resistance and Counter Electro Motive Force of a cell containing a copper plate and a coal matte plate.

g. 290

The plates rested in a trough containing solution 5% H_2SO_4. The backs and sides of the plates were varnished with a solution of g.p. in $CHCl_3$. The breadth of the copper plate was 5.5 bent in a rough sector to the matte plate which was 2.5 broad about 10 long and 0.8 thick. The depth of immersion was 6.0 so that 15 sq. cms of matte + 33 sq. cms of copper were active. The distance apart was about 3 cms. The resistance of this cell was approximately 1 ω (Ω) and the res: to d.c. 8.8 so that the counter emf to the current through the cell 0.07 amps. would be 7.8 × 0.07 = 0.55 volts. The temperature was 17°C. in the solution. The cell was then raised to a temp: of 109°C. and the res: was about 0.5 ω. The counter emf about ~~0.5~~ = 0.5 × 0.07 = 0.42 volt

Repeated experiment with a plate of matte exposing 5" (12.7 cms) breadth × 3" (7.6 cms) depth = 15 sq. in = 96.5 sq. cms. area and a copper plate 6" (15.2 cms) × 3" (7.6) with paraffined back

at 20°C.	when separated by	6.3 cms (2½")	res: 0.08 ω	emf 0.23 v.
		3.2 " (1¼")	0.04 ω	" 0.2 v.
@ 50°C.	" "	6.3 " (2½")	0.01 ω	" 0.12 v.
	" "	3.2 " (1¼")	0.02 ω	" 0.12 v.

Taking 100 sq. cms as offering 0.02 ω @ 120°F (50°C) @ 3 cms dist:
36" sq. = 936 sq. in = 6040 sq. cms. 5 sq. cms offer 1 ω suppose
then 6040 " offer $\frac{5}{6000}$ ω = $\frac{1}{1200}$ ω

Problem.

For 12 tons = 1.219×10^7 grammes daily @ 0.5 g (½ theoretical value) grammes per ampère hour = 2.066×10^7 ampère hours daily in 40 baths = $\frac{206.6 \times 10^5}{40}$ = 5.17×10^5 ampère hours daily per bath

= $\frac{5.17 \times 10^5}{24}$ = $\frac{51.7 \times 10^3}{24}$ = 2.15×10^3 = 21,500 ampère hours

whole 24 hours.

The area of matte in each bath @ 3 ampère per sq foot = 7170 sq. ft, and with sheets 36" sq. = 9 sq. ft = 800 plates. In single row this means tank length 800 ft
- double " " " " " 400 "
- triple " " " " " 270 "
- quadruple " " " " " 200 "

The res: per sq. ft will be say 0.01 ω = 100 mhos conductance.
7200 sq. ft will have 720,000 mhos.
e.m.f. due to conduction $\frac{21,500}{720,000}$ = 0.03 volts.
Power absorbed 0.03 × 21,500 = 645 Watts in each tank.
1 " " in counter emf 0.42 × 21,500 = 9,030 Watts in each bath
Total power 360,000 Watts including 10% for bath + dynamo
$\frac{360,000}{3,960,000}$ Watts = 5280 HP electrical
@ 95% eff: = 5000 HP. mechanical.

Formulae for wiring Motors.

Let D be the distance of the motor from the source cms.
E . . pressure . . source
P . . power . . motor in Watts.
η . . efficiency . . .
d . . diameter . . conductor in cms
ρ . . resistivity . . . . ohms.

Then $\frac{P}{\eta}$ is the power to be supplied

Let p be the % of fall emf allowed in leads

Then $E\left(\frac{100-p}{100}\right)$ is the emf at motor terminal

and the current $C = \frac{P}{E\eta}\left(\frac{100}{100-p}\right)$

The resistance of the leads $= \frac{8D\rho}{\pi d^2}$

" fall of potential $= \frac{8CD\rho}{\pi d^2}$

$\therefore \frac{8CD\rho}{\pi d^2} = \frac{pE}{100}$ or $\frac{8D\rho P}{\pi d^2 E\eta}\left(\frac{100}{100-p}\right) = \frac{pE}{100}$

whence $d^4 = \frac{8D\rho P\,(10{,}000)}{\pi E^2\eta\, p\,(100-p)}$ with $\rho = 1{\cdot}78\times10^{-6} = \frac{14{\cdot}53\times10^{-6}DP}{E^2\eta\, p\,(100-p)}$

for $p = 1$	$d^4 = 4{\cdot}576\times10^{-4}$	
" " $= 2$	$= 2{\cdot}312\times10^{-4}$	
$= 3$	$= 1{\cdot}612\times10^{-4}$	
$= 4$	$= 1{\cdot}180\times10^{-4}$	
$= 5$	$= 0{\cdot}9536\times10^{-4}$	
$= 6$	$= 0{\cdot}8032\times10^{-4}$	

$\times \frac{DP}{E^2\eta}$

D in cms P in Watts
E in volt + η in decimal.
d^4 in sq cms.

To express d in sq cms with D in metres $d^4 = 4{\cdot}576\times10^{-2}\,\frac{DP}{E^2\eta}$

" " " " " D in feet $d^4 = 4{\cdot}576\times10^{-2}\times30{\cdot}48\,\frac{DP}{E^2\eta}$

" " " sq inches . D " " $d^4 = \frac{4{\cdot}576}{6{\cdot}452}\times30{\cdot}48\times10^{-2}\,\frac{DP}{E^2\eta}$

$= 21{\cdot}693\times10^{-4}\,\frac{DP}{E^2\eta}$

$= 0{\cdot}002169\,\frac{DP}{E^2\eta}$

circ. mil

$= 0{\cdot}0027574\times10^{6}$

$= 27574\,\frac{DP}{E^2\eta}$

for $E = 220$ $= \frac{27574}{49284}\,\frac{DP}{\eta}$

$= \frac{746\times27574}{49284}\,\frac{DP}{\eta}$

for 1% drop	$= 41{\cdot}71$	$\frac{DP}{\eta}$
" 2% "	$= 21{\cdot}8$	$\frac{DP}{\eta}$
" 3%	$= 14{\cdot}7$	"
" 4%	$= 10{\cdot}76$	"
" 5%	$= 8{\cdot}70$	"
" 6%	$= 7{\cdot}32$	"

On the Matthiesson Standard of Conductivity in Copper

Matthiesson's original unit was 1 standard english mile of pure annealed copper wire 1/16" diam. @ 15·5°C.

Let ρ be the resistivity of this copper

Then $\frac{4 \times 1 \cdot 6093 \times 10^5 \rho}{\pi (0 \cdot 0625)^2 \times 6 \cdot 4516} = 13 \cdot 59$ B.A. units

$\therefore \frac{6 \cdot 4372 \rho \times 10^5}{7 \cdot 9173 \times 10^{-2}}$

$$\therefore \rho = \frac{13 \cdot 59 \times 7 \cdot 9173}{6 \cdot 4372} \times 10^{-7} =$$

$$= 1 \cdot 6715 \times 10^{-6} \quad @ 15 \cdot 5° \; @ 0 \cdot 388 = 6 \cdot 015$$

$$= 1 \cdot 6715 \div 1 \cdot 0602 \times 10^{-6}$$

$$= 1 \cdot 5766 \times 10^{-6} \text{ B.A. ohms}$$

$$= 1 \cdot 559 \times 10^{-6} \text{ Legal ohms.}$$

Jenkin gives the value $1 \cdot 616 \times 10^{-6}$ B.A. ohms in his book p. 251 but the table is calculated from lead through sp. gravity.

Taking the values resistance of a wire 1 metre long weighing 1 gramme as 0·1469 legal B.A. ohms (pure hard drawn copper)

$= 1 \cdot 5795$ Legal $= 1 \cdot 5935$

We have 1 c.c. of pure copper being 8·95 grammes

1 c.c. of diameter d weighs $8 \cdot 95 \frac{\pi d^2}{4}$

100 " " " d " $\frac{895}{4} \pi d^2$

$= \frac{2811 \cdot 72}{4} d^2$

$702 \cdot 93 \, d^2$

$\therefore 702 \cdot 93 \, d^2 = 1$

$\therefore d^2 = \frac{1}{702 \cdot 93}$

$$\frac{4 \times 100 \rho \times 702 \cdot 93}{\pi \quad \pi} = 0 \cdot 1469 \text{ B.A.}$$

$$\therefore \rho = \frac{3 \cdot 141593 \times 1 \cdot 469 \times 10^{-1}}{28 \cdot 11172 \times 10^{-5}}$$

$$= 1 \cdot 6415 \text{ B.A.} \times 10^{-6}$$

$$= 1 \cdot 6234 \text{ Legal} \times 10^{-6}$$

The values taken by Dr. Fleming in the "Electrician" vol XX page 471 # 512 is 1·6244 Legal microhms. for annealed copper.

The values taken by A. Gray Table 1 in Abs. Meas. is the last calculation Sandiling in $1 \cdot 6242 \times 10^{-6}$ B.A. ohms

$= 1 \cdot 6244 \times 10^{-6}$ Legal.

$1 \cdot 6195 \times 10^{-6}$ Imperial

Jamieson's Pocket-Book gives two values :-

1st Matthiessen's standard = Res: of annealed soft copper @ 0°C = 0·02057 B.A. ohms for wire 1 metre long and 1 mm: in diam.

$$\therefore \frac{100\rho}{\frac{\pi}{4}\,0{\cdot}01} = 0{\cdot}02057 \qquad \therefore \rho = \frac{0{\cdot}785398 \times 2{\cdot}057 \times 10^{-4}}{1{\cdot}0 \times 10^{3}}$$

$$\therefore \rho = 1{\cdot}6156 \times 10^{-6} \text{ B.A. ohms}$$

$$= 1{\cdot}5977 \times 10^{-6} \text{ Legal ohms}$$

$$= 1{\cdot}57135 \times 10^{-6} \text{ True "}$$

2nd Matthiessen's standard

Res: of 100" of pure annealed soft copper wire weighing 100 grains @ 60°F = 15·5°C. = 0·1516 B.A. "

$$@\ 0°C = \frac{0{\cdot}1516 \times 0{\cdot}2064}{0{\cdot}2190}$$

$$= 0{\cdot}142288 \text{ " @ } 0°C.$$

2·540 cms weigh 0·0648 grammes.

1 cm weighs $\frac{0{\cdot}0648}{2{\cdot}540}$ "

$= 0{\cdot}025511$ "

but 1 cm: if its section were 1 sq. cm: would = $\frac{8{\cdot}90}{8{\cdot}95}$

$\therefore$ the section was $\frac{0{\cdot}025511}{8{\cdot}90}$ or $\frac{0{\cdot}025511}{8{\cdot}95}$

$$\text{and } \rho = \frac{0{\cdot}142288 \times 2{\cdot}5511 \times 10^{-2}}{2{\cdot}074 \times \frac{8{\cdot}95}{8{\cdot}90} \times 10^{3}}$$

$$= \frac{0{\cdot}364504}{22730} \times 10^{-4} \text{ or } 22605$$

$$= 1{\cdot}6041 \times 10^{-6} \text{ or } 1{\cdot}6120 \times 10^{-6} \text{ B.A.}$$

$$= 1{\cdot}5881 \times 10^{-6} \text{ true or } 1{\cdot}5969 \times 10^{-6} \text{ Legal}$$

Jamieson's	tables	p. 1946	gives	soft copper	1615 true = 1620 Legal	
				hard "	1642 true = 1647 "	
Everett's	tables	gives	p. 159	soft copper	1584 Legal 1580 Imp.	
				hard drawn	1620 " 1616 "	
Anthony & Brackett		give	p. 504	pure copper	1611 C.G.S.	
Houston's	Dictionary	gives	p 531	from Matthiessen's results		
				soft copper pure	1·597 Legal ×10⁻⁶	
				hard " "	1·632 " "	
Mascart	gives	p. 748		soft copper pure	1·584 Legal 1580 Imp	
				hard " "	1·624 " 1617	

Magnetic Susceptibility of three samples of Iron ore. Rough comparison.

13.5.90.

Three samples of sulphide iron ore from Evans Copper cliff and Stobie mines were pulverised & sieved thro' 60 mesh. They were then slightly mixed with water to render the powder cohesive, and portions of ~~the~~ each pressed in a hydraulic mould to cylinders of 2.5 cms diam: and about 6 cms long. A magnetometer was mounted with two solenoids one on each side of it and the zero adjusted until 0.5 ampere passing through the two solenoids gave rise to no disturbance of the needle. The cylinders were then introduced into one solenoid. The mean deflections were

Stobie 3.5 Evans 1.0 Copper Cliff 0.75

On the Field winding necessary for the motor described on the next page.

Let 50 lbs. of copper be used on each limb.

Let x be the ext: diam: of winding, d the internal and l the length of the cy. of the winding. $= 0.75 \times 8.9 = 6.67$

Then $0.7854\,(x^2 - d^2)\,l\sigma = 22680$

$$x^2 = \frac{0.7854\,l\sigma d^2 + 22680}{0.7854\,l\sigma} = d^2 + \frac{22680}{0.7854\,l\sigma}$$

with $l = 25$

$$= (15.2)^2 + \frac{22680}{7.854 \times 10^{-1} \times 2.5 \times 10^{1} \times 6.67}$$

$$+ \frac{22680}{131} =$$

$$231 + 173$$

$$= 404$$

$x = 30$ Depth of winding 1" including insulation

Assume the average p.d. upon the coils considered as shunt coil to be 1½ volts and the p.d. on each = 3.75 volts.

The surface of each coil is $25 \times 628 = 1670$ sq. cms and at 20 sq. cms. per Watt this gives 83.5 Watts @ 3.75 volts = 22.3 amp.

The res: of the coil must thus be $\frac{3.75}{22.3} = 0.0168 = K = \frac{(261-23)10^{-6} \times 22}{}$

so that $d = -0.02 + \sqrt{\{0.00014 + 0.00153\sqrt{\frac{2246}{0.0168}}\}}$

$0.00153\sqrt{133700}$

0.00153×365.7

0.5595

0.5599

$+ 0.7483$

$= 0.728$ cm.

$= 0.287"$ #2 B&S. 0.30" correct:

in 9" there will be 27 turns, and in 0.76" 2.5 layers = 675 turns in all and with 22 amperes 14.90 a.t. while 5000 are needed.

Mean turn = 1.8 ft 1285

If the current in the coil be kept the same but each limb to be doubled in ~~so~~ then $d = -0.02 + \sqrt{\{0.00014 + 0.00153\sqrt{6.6850}\}}$

0.00153×2.59

0.4120

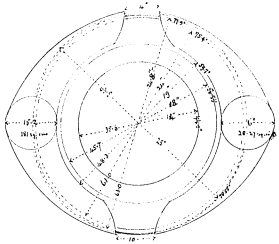
$\sqrt{0.41215}$

0.6422

$= 0.622$ cm $= 0.245"$ #4 nearest typ.

36 turns per layer × 3 layers = 108 turns. correct = 0.25"

1/8



Volume of armature $0.785\,(24^2 - 18^2) \times 0.8 \times 8 = 1267$ c.i. @ 0.35 = 443 lbs.

Breadth 8" (20·3) but: diam: on iron wire 24" (61)
but . . . . 18" (45·7)

Thickness of bars above top 0·4" (1·02)
below 2·0" (5·1)
on sides 0·4" (1·02)

Sectional area of each bar. 0·85 sq cm.

Breadth of each bar above $\frac{73.9}{200}$. 0·386" say 0·35" (0·84)

Res: of each upper bar approx $\frac{1.7 \times 35}{0.85} = 70$ microhms.

. . . under . . $\frac{1.7 \times 22}{10 \times 0.6} = 7.5$

Res: of each complete turn with joint 80 . approx
. . entire ring 4,000 .
. . . armature 1,000 . = 0·004

fall of potential with 500 amperes = 0·5 volts.

Revolutions of armature per minute 300
. . . . second 5

Peripheral speed 1950 ft: per min: = 1990 cms per sec.

Calculated total flux 4.2×10^6

Electromotive force $4.2 \times 10^6 \times 5 \times 100 = 21 \times 10^8$

There will be 200 bar every pair in multiple.

180 sq cms: in field magnets @ 15×10^6 = 2.7×10^6 lines.

Surface of polar face covering armature =

$0.8 \left\{ \frac{0.785}{4} (24^2 - 19^2) + 8(2g) \right\}$

16g + 312

481

385 sq in. = 2480 sq. cms.

The reluctance = $\frac{2 \times 1.27}{2480} = 0.00102$ but.

Allowing 3 times the reluctance as the total in est. = 0.003

The ampere turns for each pair of magnets = 10,000 = 5000 on each limb

(133)

Electrical Design for a Street Car motor of 10 kwts. power to run at 300 revolutions per minute at 500 volts & 50 amps. amperes

The diameter of the armature gramme ring happens to be 24" (61) externally and 20" (50·8) internally, and 6" (15·2) broad.

The section of this armature will then be $5.1 \times 15.2 \times 0.8 = 62$ sq cm which @ 16,000 lines = 992,000 say 1.0×10^6

$$s \times 10^6 \times w = 500 \times 10^8$$

$$w = \frac{10^{2}}{2} = 5000$$

so that 5000 wires must be in series round the whole armature and 2.0×10^6 useful lines have to be furnished.

In 4 layers this will represent 1250 wires all round.

At the diameter of 19·5" this circumference = 61·25" and allowing for fibre 60" this leaves 0·048" for each wire and with 0·018" for insulation 0·030" = #20 B.W.G. 1225 c. mils.

The resistance of the armature will be about $\frac{5000}{2} \times 1.4 \times 8.5 \times 10^{-3}$ $= 1.25 \times 1.4 \times 8.5 =$ 14·9 ω

If required to deliver 21 volts @ 500 amperes.

Let D be the ext: diam: of the wire armature cms
d - - int: - - - - - -
b - - breadth

Then the section is kb(D − d) where k is a constant less than unity) representing the ratio of iron to volume. say 0·8

The weight of iron is $0.7852\,b(D^2 - d^2)k\sigma$ where σ = sp: gr: of iron

If φ be the density of flux permissable in the armature

$$kb(D-d)\varphi = \Phi \text{ the total flux}$$

and $5\,w\Phi = 2.1 \times 10^8$ where w = number of bars

$$w\Phi = 4.2 \times 10^8$$

Let t be the thickness of the winding above
- - - res: of the armature between its plane

Then $\frac{t}{kb}\rho w$ is the resistance of each turn

$\frac{\rho w^2}{2}$ - - - the whole armature

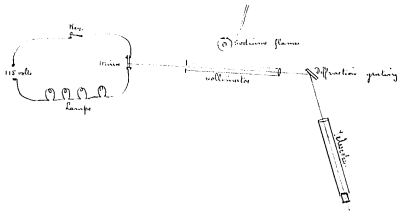
For a trial value let Φ be 4.2×10^6 bifurcating into two streams each of 2.1×10^6 requiring at a density of 17×10^6 1.24×10^6 = 124 sq. cms @ 2" depth (5·1) 24·3 cm 9·57" ÷ 0·8 = 12"
2·5" - (6·35) 19·5 " 7·68" ÷ 0·8 = 9·6"
3" - (7·62) 16·3 " 6·42" ÷ 0·8 8·"

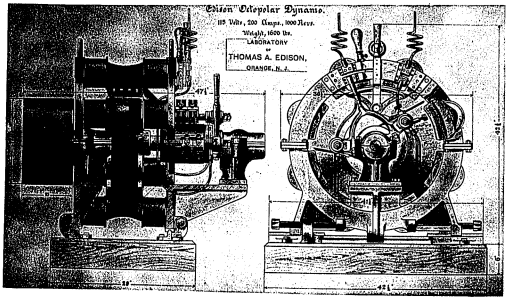
The int: diam: will be 18" and the circumference 56·5"5

With 200 bars the space allotted to each will be 0·283" and allowing for insulation 0·25".

The field magnets have to supply 4.2×10^6 usefully in say 5.5×10^6 allowing for leakage. If there are two fields Each must create 2.75×10^6. At 15000 lines per sq. cm. their area is $\frac{2.75 \times 10^6}{1.5 \times 10^4} = 1.83 \times 10^2 = 183$ sq. cms = 15·3 cms in diam.

= 6".





Experiment on Electric Current Sheet.

14. I. 90. A slip of silvered glass 5 × 3·3 and 0·69 thick was held in the a nearly vertical plane between two copper clamps on a wooden block. The reflecting film of metal offered a resistance between the clamps of 24 ω. The reflector was placed about 20 cms from the slit of the spectrometer and a Bunsen burner with a sodium flame was then placed in such a position that the reflected image of the flame fell upon the diffraction grating. The two D lines were then focussed upon the hair line of the telescope eye piece. Under these conditions, a current supplied from the 115 volt circuit through 3, 2, + 1 lamps was passed through the metal reflecting film, i.e. 0·17 0·25 + 0·5 amperes. The direction of the current was first horizontal and subsequently by placing the mirror + support on its side, vertical; but although contact was made by a key, and a very slight displacement could have been observed, no movement of the image could be observed, although at first it was imagined to do so. The object of the experiment was to ascertain whether assuming electric current to be ether flow, the passage of electricity along the surface of a conductor in any way altered the direction of a beam of light incident upon it. Thus far the result is negative.

On the conditions necessary to obtain a ballistic galvanometer with a period of three or four minutes.

The mass and suspension torsion are to be minimum. The moment of inertia, and magnetization, maximum.

$$T = 2\pi\sqrt{\frac{I}{mH}}$$

where I is the moment of inertia about the vertical, m the magnetic moment of the ballistic system and H the field. mH represents the moment of the resultant directive force on the magnetic system round the vertical. By making the system sufficiently astatic this resultant moment can be indefinitely diminished. There is however a practical limit for sufficient directive force must be left to bring the system back to zero. I must therefore be increased.

On the Magnetic circuit of the New Car motor

continued from pages 132 and 133

The reluctance of the air space is 0.00102

" " of two cores 10" long (25.4 by 181 section)

" " " $\frac{25.4}{181} \times \frac{1}{300} = \frac{25.4}{54300}$ 0.00047

" " one yoke of wrought iron 25" long (63.5 by 180 section) $= \frac{1}{200} \times \frac{63.5}{180}$

$= \frac{63.5}{54000}$ 0.00118

" " of a cast iron hood mean path $12" \times 12$ sq. in $\frac{25}{76} \times \frac{1}{200} =$ 0.00764

opposite hood 0.00764

" " armature mean path 30" long by 12.4 sq. ins × section @ 18000 . 300

$\frac{30}{12.4 \times 300} =$ 0.00808

Circuit $= 2\,(0.00084) + \frac{0.00204 + 2(0.00328)}{2} + \frac{1}{2}\,(0.00118 + 0.00047)$

$= 2\,(0.0027) + 0.00083$

$= 0.0052 + 0.00083$

$= 0.0062$ lines.

Entrefer	0.00102
Armature	0.00184
Hoods	0.00328
Bows	0.00059
Yokes	0.00047
	0.00617

If the hoods be made of sufficient section the total reluctance will fall to 0.003, and the magnetomotive force for 18 volts $= 3.6 \times 10^4$, and allowing 25% for leakage $= 4.5 \times 10^4$.

$4.5 \times 10^4 \times 3.0 \times 10^{-3} = 13.5 \times 10^3 = \frac{13500}{1.287} = 10740$ AT per pair

5370 AT per limb.

On the conductors required to carry 100 amperes from the Phonograph Works Engine Room to the New Toy Building a distance of 350 feet at 7 volts fall.

Res $= 0.07\,\omega \div 700 = 0.01 \div 100 = 0.0001\,\omega$ per foot.

= equivalent to a # 1 wire, or 6 # 10 wire. approximately.

$= 700 \times 6 = 4200$ ft. of # 10 wire $= 4.2 \times 10^3 \times 5.44 \times 10^{-2} = 22856 \times 10$

= 220 lbs. of # 10 wire (stranded say) 230.

1 c.c. of 98% copper has a res. of 1.778×10^{-6} ω @ 20°C.
1 foot " " " " 1 grm. " " " 5.19×10^{-6} ω " "
1 " " " " 1 sq. in. " " " 8.02×10^{-6} ω " "
1 " " " " 1 sq. mil " " " 8.02×10^{-12} ω " "
1 " " " " 1 mil " " " 10.70 ω

pure copper has a resistivity of 1.624×10^{-6} ω @ 0°C.
1.750 " @ 20°C.
99.7 " 1.767 " " or 1 mil foot .. 10.635
98 " 1.785 "

$$D^2 = 0.7854\, l\,(C^2 - c^2)\sqrt{\frac{\rho\sigma}{m\tau}} \qquad \sigma = 8.95$$

$$d^2 = 1.2732\sqrt{\frac{m\rho}{\tau\sigma}}$$

$$m_{gm} = (0.7854)^2\,\frac{\tau\sigma}{\rho}\,d^4$$

For 98% copper @ 8°C
or 100% " " @ 10°C.

$$= 0.6168\,\tau \times \frac{8.95}{1.7\times10^{-6}}\,d^4$$

$$= 3.24\,8 \times 10^6\,\tau \times d^4 \quad (1.7\times10^{-6})$$

$$= 3.063 \times 10^6\,\tau \times d^4 \quad (1.8\times10^{-6})$$

$$m(\text{lbs}) = \frac{2.979 \times 10^{-7}\,\tau\,d^4\,(\text{mils})}{2.807 \times 10^{-7} \text{ for } 1.8\times10^{-6}}$$

A wire offering 1 ω res (τ = 1) and of diam 0.1

$$m = 3.248 = 0.736 \text{ lb.}$$

$$d_{inc} = \frac{0.02326}{0.0237} \sqrt[4]{\frac{m}{\tau}}\,\tau_{inc} \quad \text{or} \quad \text{for } 1.8\times10^{-6}$$

$$d_{mil} = \frac{4.292}{4.3145 \times 10} \times 10^4 \sqrt[4]{\frac{m\,\text{lb}}{\tau_{inc}}}$$

$$\tau_{inc} = 3.1645 \times 10^{-7} \cdot \frac{m}{d^4}\,\tau_{inc}$$
$$= 3.079$$
$$3.266 \quad (1.8\times10^{-6})$$

$$\tau_{inc} = \frac{3.779 \times 10^6}{3.357}\,\frac{m\,\text{lb}}{d^4_{mil}} \quad \text{for } 1.8\times10^{-6}$$

In the wire tables for wire at higher temperatures.
These are

$$m_{lbs} = 2.9327 \times 10^{-7}\,\tau_{inc}\,d^4_{mil}$$

$$d_{mil} = 4.3014 \times 10 \sqrt[4]{\frac{m\,\text{lb}}{\tau_{inc}}}$$

$$\tau_{inc} = 3.1494 \times 10^6\,\frac{m\,\text{lb}}{d^4_{mil}}$$

General Formulae for the Winding of Magnets.

Let τ be the number of ampere-turns required on the spool
m - - weight of copper allowed in grms.
c - - diameter of the core cms
C - - - - - core after winding cms.
d - - - - - wire cms.
D - - - - - wire covered cms
t - - thickness of covering $\left(\frac{D-d}{2}\right)$ cms
l - - length of the core between flanges.
σ - - sp. gr. of copper 8.95
ρ - - resistivity of copper 1.7 microhms.
β - - limiting number of watts per sq. cms. of surface per watt.
λ - - length of wire on the spool cms.
r - - resistance - - - hot. ω.
ε - - p.d. on the spool - - - volts.

Then the winding space $= 0.7854\, l\,(C^2 - c^2)$
of this volume $0.7854\, d^2$ is occupied by copper
so the volume of copper is $\frac{(0.7854)^2\, l\, d^2\,(C^2-c^2)}{D^2}$

. . weight . . $m = \frac{(0.7854)^2\, l\,\sigma\, d^2\,(C^2-c^2)}{D^2} = \frac{\beta d^2}{D^2}$

. . length . wire $\lambda = \frac{0.7854\, l\,(C^2-c^2)}{D^2}$

. . number of turns per layer $= \frac{l}{D}$

. . - - - layers $= \frac{C-c}{2D}$

. . total - - turns $= \frac{l\,(C-c)}{2D^2}$

. . length of the mean turn $= \pi\left(\frac{C+c}{2}\right)$

. . res: of the spool $r = \frac{\lambda\rho}{0.7854\, d^2}$ ohms

$= \frac{l\rho\,(C^2-c^2)}{D^2 d^2}$ ohms

. . current in the spool $= \frac{e\, D^2 d^2}{l\rho\,(C^2-c^2)}$ amperes

. . (heat) energy) - - - $= \frac{e^2 D^2 d^2}{l\rho\,(C^2-c^2)}$ watts

. . energy per unit surface $h_f = \frac{e^2 D^2 d^2}{\pi C l^2 \rho\,(C^2-c^2)}$ watts per sq. cm.

. . ampere turns $\tau = \frac{l\,(C-c)}{2D^2} \times \frac{e\, D^2 d^2}{l\rho\,(C^2-c^2)}$

$= \frac{e\, d^2}{2\rho\,(C+c)}$

In every practical problem c is given while e is susceptible of little variation. ρ, σ, β, β, are known. a and m are fixed limits that must be complied with by the use of suitable values of d and l.

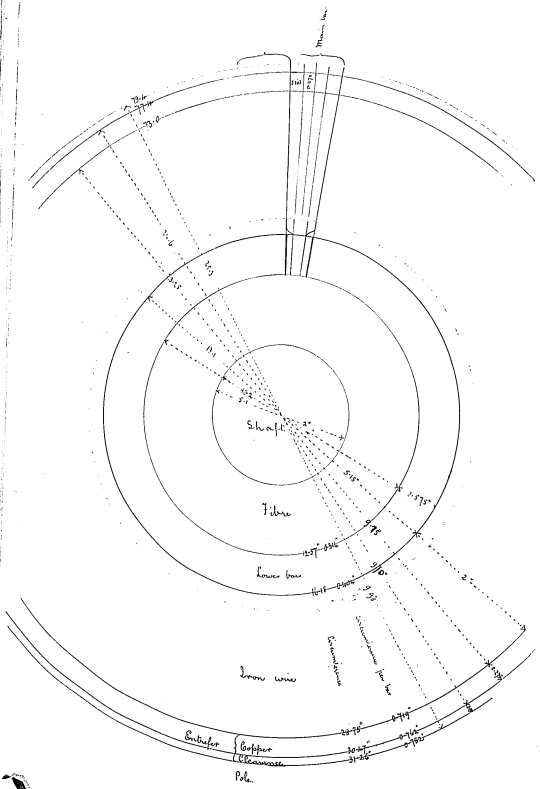
The final equations are

$$d = \sqrt{\frac{2\rho\tau\,(C+c)}{e}} \qquad d^2 = \frac{2\rho\tau\,(C+c)}{e}$$

(1) or $d = 0.002\sqrt{\frac{\tau}{e}(C+c)}$ $\qquad d^2(\beta - m) = 2mlt + mt^2$

(2) $m > \beta\left(\frac{d}{D}\right)^2$ $\qquad d^4(d+t)^4 < \frac{l\sqrt{h\pi\sigma\rho\,(C^2-c^2)}}{c}$

(3) $l > \frac{c\, d^2}{\sqrt{h\pi\sigma\rho\,(C^2-c^2)}}$



Modification of the Street Car Motor

Sprague model to suit 20 volts.

The # 6 500 volt model at present in use has 62 dis: in its armature and 12 wires in each = 744 wires all round. Its speed is from 1025 to 1060 revs per min: mean 1050 or at abt 17.5 revs: per second. $\therefore\ 17.5 \times 744 \times \phi = 500 \times 10^8$

$$\phi = \frac{5.0 \times 10^{11}}{1.75 \times 0.744 \times 10^{10}} = \frac{5.0}{1.30} \times 10^1 = 3.84 \times 10^8$$

Assuming the same speed to be retained in a bar armature of the gramme ring type with 20 volts.

$$\frac{744 \times 18}{500} = 14.88 \times 18 = 267.84$$

$$17.5 \times 267 \cdot 3.84 \times 10^8 \times n = 18 \times 10^8$$

$$n = \frac{18 \times 10^8}{1.75 \times 3.84 \times 10^7} = \frac{18}{6.72} \times 10 = 26.8$$

say 30 bars with a little weaker field.

The diam: of the armature over a bound is $9\frac{7}{16}" = 9.7"$

" " " now cor will be about 9".

" area of iron will be about 9" × 10" × 6.48 × 0.8 = 464 sq. cms.

If the thickness of the ring be 2" the section will be . 208 " .

The flux being $3.84 \times 10^8 \div 2.08 \times 10^2 = 1.92 \times 10^6 = 19.200$ lines per sq.

This must be brought down to about 15.000 making $\frac{26.8 \times 19.2}{15} = 34.3$ bars

As a first approximation 40 bars may be used.

The circumference of the armature $\frac{9.7 \times 3.14}{40} = 30.458" \div 40 = 0.762"$

If 0.162 bar be used 0.648" will be occupied by them at the surface leaving 0.114" for four thicknesses of insulation = 0.029" each.

The area of the upper annular bar space is $0.7854(9.7^2 - 9.15^2)$

$0.7854(94.09 - 83.72)$

$0.7854 \times 10.37 = 8.146$ sq. in.

The area of the lower bar space is $0.7854(5.15^2 - x^2)$

$\therefore\ -0.7854x^2 = 8.146 - 2.7854(26.52)$

$x^2 = -10.37 + 26.52 = 16.15$

$x = 4.019$ say 4.0

Lower bars have an upper breadth of 0.575" full allowing ⅛ nearest size is 9/16" = .056 The breadth is 0.404" theoretical + allowing 0.029" for insulation leaves 0.375" for the upper breadth ⅜". 40 of these bars 12" long will be needed = 40 feet of bar. The upper bars will be 160 in number 0.162" in breadth and 0.275" deep.

Description of the 10 kilowatt 1000 volt – 20 volt Transformer as completed from electrical designs recorded in the earlier part of this book.

For the general dimensions reference may be made to the Dynamo this print book where they are entered in due form. The section of the armature is correctly given on page 85 except that 12 instead of 14 large wires are braided upon each of the outer 2 layers. That is to say owing to the braiding only 24 wires could be inserted instead of 28 as originally designed. The diam: of the armature over the brass wire bands is rather less than 7.5". The armature body is as standard #14, but with the slots increased to 96 at each end. Winding 1 # 17 B.S. 0.0453 sq.g brass wire
12 # 11 B.S. 0.091 sq over wire

The bore of the fields is 7.85" allowing 0.15" clearance.
The fields are regular F.I.C. with the #4 keeper, & zinc.
The bed plate is specially cast.
The winding of the fields is 60 lbs. of # 11 B.W.G. on each limb 120 lbs in all = 1.0 cwt. approx, and when joined up in multiple are = 0.5Ω.
The series winding is in a separate coil at the base of each limb of which height it occupies about 0.75; It consists of 96 turns see p. 104 of # 14 B.W.G 0.093" 48 turns on each limb 4 layers high, 12 around.

Test of a small miner's lamp battery at Mr Hastings request

This battery consists of 4 cells contained in a wooden box 15.2 high × 10 × 10. It weighs 4 lbs 8 oz. alone when charged, and with its lamp and cover attached 4 lbs 14 oz. The resistance of the lamp is 14.4 hot, 2½ cp. The p.d. on the lamp was 5.6 volts and the current 0.4 ampere. The lamp was then replaced by 14.4 of platinoid res:, and observations taken Jan: 16th

No. of obs	Jan 16th time	Time from start	EMF volts	P.D. volts	C. amps	C²	r ω	Batt. Eng. Watts	Ext. Eng. Watts			
1	10.0	0	7.0	5.75	0.41	0.17	3.0	2.38	0.51			
2	11.0	1.0	6.95	5.7	0.40	0.16	3.0	2.24	0.48			
3	12.0	2.0	6.91	5.68	0.40	0.16	3.0	2.24	0.48			
4	13.0	3.0	6.73	5.24	0.37	0.14	4.0	1.96	0.56			
5	13.30	3½	6.3	4.96	0.35	0.12	3.83	1.68	0.46			
6	14.0	4.	5.94	3.11	0.22	0.05	12.0	0.7	0.60			
7	14.30	4½	4.02	2.00	0.14	0.02	14	0.28	0.28			

The output of the cells is thus (practically) 1.5 amp. hrs. Second test after recharging) cell with Solution of $6\,H_2O$ & H_2SO_4 + KNO_3

No. of obs	Jan 18th Time	Time from start	EMF volt	P.D. volt	C. amp:	C²	r ω	Batt. Energy Watts	Ext. Energy Watts			
1	9.0	0	7.1	5.62	0.40	0.16	3.7	2.24	0.59			
2	.10	.	6.82	5.3	0.38	0.15	3.8	2.1	0.57			
3	.30	½	6.68	5.2	0.37	0.14	4.0	1.96	0.56			
4	10.0	1.0	6.28	4.9	0.35	0.12	4.0	1.68	0.48			
5	.30	1½	6.18	4.34	0.31	0.096	6.0	1.34	0.58			
6	11.0	2	5.62	2.98	0.21	0.044	10.0	0.62	0.44			
7	11.30	2½	4.80	2.48	0.18a	0.032	10.0	0.45	0.32.			
	a third trial gave even worse results											

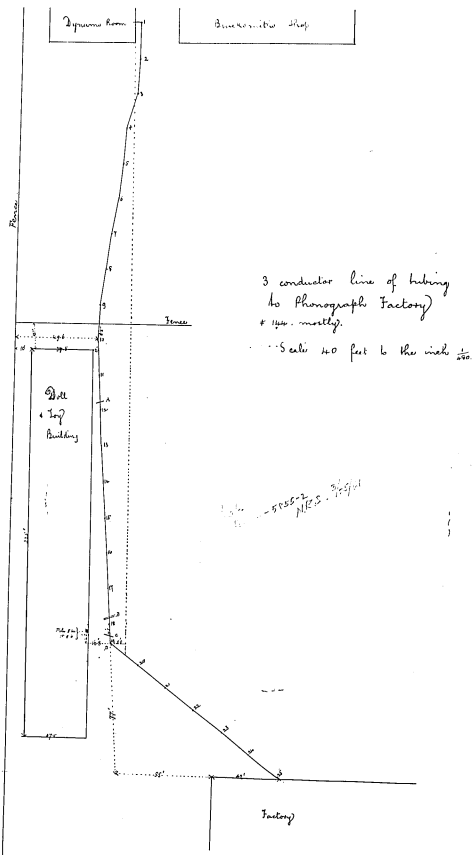


Diagram shewing the position and course of the line of electric pipe conductors from the Laboratory to the Phonograph Works as altered Jan. 90.

The tubes were taken up between boxes #s 10 and 29, and relaid as shewn. A short length (11.5') is inserted between 18 & 19. The position of the corner D (box # 19) is shewn with reference to the laboratory line, an offset from the long building, and a pair of lines with the factory.

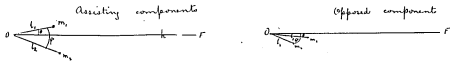
Pipes cross above the tube at A B & C.

A is a 3" water pipe, 1 foot above. & distant 4.5' from 12, mm

B . . 12" rectangular drain from the pond 1.5' feet above & 14.7' from 19

C . . 3" water pipe 6" above, & distant 4.5' feet from 19.

On the conditions of equilibrium direction in an astatic suspended system.



Let O be the center of the astatic system

$m_1 l_1$ be the moment of one component

$m_2 l_2$ . . . . the other.

φ . . angle between the two

θ . . . of equilibrium.

Then $l_1 m_1 h \sin\theta - l_2 m_2 h \sin(\theta + \varphi) = 0$

$$\therefore \frac{\sin(\theta+\varphi)}{\sin\theta} = \frac{l_1 m_1}{l_2 m_2} = n \text{ say.}$$

$$\sin\theta\cos\varphi + \cos\theta\sin\varphi = n\sin\theta$$

$$\sin\theta(\cos\varphi - n) = -\cos\theta\sin\varphi$$

$$\sin^2\theta(\cos^2\varphi - 2n\cos\varphi + n^2) = (1-\sin^2\theta)\sin^2\varphi$$

$$\sin^2\theta(1 - 2n\cos\varphi + n^2) = \sin^2\varphi$$

$$\sin\theta = \frac{\sin\varphi}{\sqrt{1-2n\cos\varphi+n^2}}$$

When $n = \infty$ $\theta = 0$

$n = 0$ $\theta = -\varphi$

$n = 1$ $\sin\varphi = \sin\varphi / 2\sqrt{1-\cos\varphi} = \sin\varphi / 2\sin\frac{\varphi}{2}$

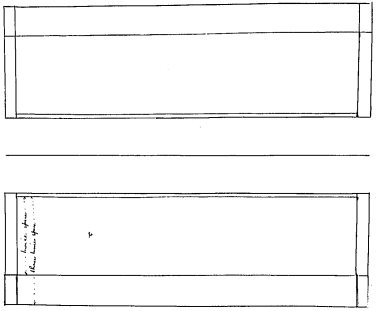
$$= \frac{2\sin\frac{\varphi}{2}\cos\frac{\varphi}{2}}{2\sin\frac{\varphi}{2}} = \cos\frac{\varphi}{2}$$

In this case if $\varphi = \frac{\pi}{2}$ $\theta = \frac{\pi}{4}$

If $\varphi < \frac{\pi}{2}$ $\theta > \frac{\pi}{4}$

Analysis of the Edison Dynamo Magnetic Efficiency.

Number of Spires	Speed Revolutions per min.	Power	Power expended all work	Field Flux Φ $\times 10^{-6}$	E volts	Field Flux Φ $\times 10^{-6}$	E volts	X Section Field Flux Φ sq. cm.	Field Flux Φ lines per sq. cm.	X Section Field Magnet Φ sq. cm.	Field Flux Φ lines per sq. cm.	X Section Field Magnet Φ sq. cm.	Field Flux Φ lines per sq. cm.	Outer Diameter	Inner Diameter
1	1900	31·67	528	0·7676	125	0·757	131·6	127	6·2000	127	6·2000				



For test of this coil on completion see table on page 101.

On the winding of a still more powerful Phonoplex Induction coil intended for special work.

On page 93 is given the winding of a coil whose test is shewn on 101 with theoretical considerations on page 103. The effect of using this coil increasing the time constant from 0.018 to 0.022 seconds ratio (2.33) was to increase the practical working distance from 175 miles to 250 approximately (1.4) so that judging from this experiment the limiting distance varies as the square root, or even less rapidly than the square root of the coil power.

The time constant of a coil without iron we know to be independent of its length, but if the coil is too short some effect must be lost when an iron core is used. We may therefore take the last coil of page 93, add 25% to its length, keep the resistance the same, and double the annular coiling space, while doubling the cross section of core.

It is not yet known whether the power of different coil having the same time constant and general dimensions is practically independent of their resistance.

L was	10.6	and will now be	13.3	=	~~5.24~~"
l -	1.9	" " "	12.4	=	4.88"
r -	1.9	" " - -	2.687	=	10.6"
y -	2.15	- - - - -	2.94	=	1.16"
x -	6.15	- - - - -	~~18.84~~ 8.66	=	3.41"

$$d = -0.007 + \sqrt{\left(0.00153\sqrt{\frac{646.5}{5}}\right)} \Big/ \sqrt{129.3}$$
$$+ \sqrt{0.00153 \times 11.37}$$
$$+ \sqrt{0.01714}$$
$$+ 0.132$$

$= 0.125$ mm

$= 0.049"$ = #18 silk covered wire

The mean diameter is 2.24" = 7.04" circumference = 0.59'
The diam: covered = 0.052". There will thus be 90 turns to the layer + 1.13" dep. = 20 layer = 1890 turns = 1115 ft = $4.3 \times 10^{-3} \times 1.115 \times 10^3 = 4.80$ ω.

Trial of a Transformer previous to placing it in its box underground.

22nd Jany. 90.

Speed 1320 revolutions per minute.
Pressure at primary terminals 1060 volts Current 1.7 ampere
- - secondary - 20.0 - - 40 - through fields.
Watts absorbed 1800 Watts utilized 800 in fields.
- lost in primary armature 15.
- absorbed in (rotating) armature through fields 980.

Transformer # 1 ran from 10 to 18 o'clock almost uninterruptedly. At 18 o'clock, the temperature of the cores and framework was 130° F (55°C). That on the armature 135°F (57°C)

Let r be the rad. of the ring
θ be its inclination to H.
Then the lines included will be $\pi r^2 H \sin\theta$
and if this ring be revolved, the emf e generated is

$$e = \frac{d(\pi r^2 H \sin\theta)}{dt} = \pi r^2 H \cos\theta \frac{d\theta}{dt}.$$

Let the no. of revs. per sec = p Then $\frac{d\theta}{dt} = 2\pi p$.
and $e = 2\pi^2 r^2 H \cos\theta\, p$.
If there be n turns and the mean radius is R

$$e = 2n\pi^2 R^2 H \cos\theta\, p$$

or if the total area $A = n\pi R^2$ be inserted

$$e = 2\pi A H \cos\theta\, p$$

and the maximum e.m.f. E

$$E = 2\pi p A H$$

or if the total induction AH at maximum be Φ

$$E = 2\pi p \Phi$$

2.

Telephonic Experiment with revolving coil

(1142)

22nd January 90.

A ring about 15 in diam. was roughly mounted in wooden horizontal bearings. It was caused to rotate about a horizontal diameter by pulleys & multiplying gear. On the ring was wound five platinoid wires in two coils of 100 turns each. One turn of the driving wheel made about 21 turns of the coil. When driving at 40 revolutions per minute with the earths vertical field assumed at 0.2 the e.m.f developed, at the maximum by the coil, whose terminals were connected to collector rings & strips would be in each 100 turn section

$$\frac{40}{60} \times 2\pi \times 21 \times 0.7854 \times 225 \times 100 \times 0.2 \times 10^{-8} \text{ volt}$$

$$0.667 \times 2\pi \times 2.1 \times 0.7854 \times 2.25 \times 1.0 \times 2 \times 10^{-4} \quad "$$

$$9.918 \times 10^{-4} \text{ volt} = 0.00299 \quad "$$

With both coils in series $\quad 0.006$ "

No sound was heard in the telephone when the latter was directly connected with the rotating coil but when a vibrating armature was in the circuit as a rapid make and break the sound produced by rotating the armature was quite distinct.

Sewing Machine Tests with Low Tension Dynamo.

23rd Jany. 90. With the phonograph motor revound as described on page 127. The following results were obtained.

P.D. of 6 volts at his bars. Res. of field 3.4 ω armature 0.33 ω

No. of lbs.	Revs. per min.	Current	P.D. at terminals	Revs. of Sewing Machine	Watts absorbed	Current in field	Watts in field	Current in armature	Watts in armature	Back emf in armature	Emf. developed in armature	?
1	400	7.5	5.1	800	38.3	1.5	7.65	6.0	12.0	2.0	2.1	4.60
2	0	14.8	4.3	400	63.6	1.26	5.38	13.5	58.	4.3	"	
3												
4												

at this speed and power the work done by the machine was very satisfactory, it sewed through 4 ply muslin without any great difficulty.

Required the number of K40 cells to produce the same results.

Let n be the number with 0.05 ω int. res. and 0.7 emf volts

Then $0.7n - 7.5 \times 0.05n = 5.1$

$0.7n - 0.375n = 5.1$

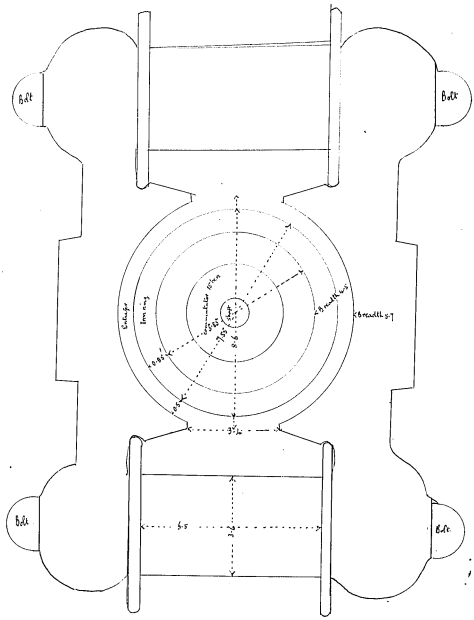
$0.325n = 5.1$

$n = 16$ cells approximately.

of which 7.3 are required to make up the p.d. at terminals

No. of cells	e.m.f each	Total emf.	res. of each	Total res	current amp.	field in battery	p.d. at terminals with	Watts in circuit	Watts lost in battery	Lost in motor field	Watts usefully employed	?
16	0.7	11.2	0.05	0.8	7.5	6	5.2	39	45	7.7	31	26
10	0.7	7.0	0.025	0.25	7.5	1.88	5.1	52.5	14.8	7.7	31	24

Full size. Cast iron.



Armature winding

Gramme ring 15 sections

Each section 11 wire bond 3 high # 22 BWG D.C.C. 0.028"

495 wire all round = 210 ft = 54' equivalent to 0.71 w. ½ lb.

Field winding

14 oz. on each limb of # 23 BWG. 0.025" D.C.C.

1 lb. 12 oz. in all.

Speed 2400 revs. per min = 1900' per min at periphery.

On the best winding for a pump motor of dimensions shewn to be operated by a 440 battery.

The work actually required to be done is stated at 125 gallons of water 50 feet high per hour. $3.786 \times 10^3 \times 1.25 \times 10^3 \times 4.5 \times 10^2 \times 3.05 \times 10^1$

$= 3.786 \times 1.25 \times 4.5 \times 3.05 \times 10^7$ ergs per sec. $= 6.5 \times 10^8$ ergs per sec.

$= 6.5 \times 44191 \times 10^{10}$ Foot lbs $= 6.37 \times 10^{14}$ per hour $\div 3.6 \times 10^3 = 1.77 \times 10^{11}$

$= 17.7$ Watts.

In the absence of definite information we may assume the efficiency of the pump to be 0.5 so that 35.4 Watts will be needed from the motor. The motor itself may be allowed to have a gross efficiency of 0.50 thus demanding a development of 70.8 Watts by the battery, suppose 75.

If 15 volt + 5 amperes be adopted we require 21 cells @ 0.7 volts and with each cell 0.05 ω. the res: = 1.05 ω. It is therefore required to wind the motor for 1 ω res:

The radial winding space is $0.7854\,(8.4^2 - 7.55^2) = 10.65$ sq. cms. the total is $4.5 + 0.85 = 5.3$ so that the actual space above the ring allotted to winding = 56.5 c.c. Allowing as much for the interior space = 113 c.c., and reducing for insulating division leaves about 100 c.c. ρ may be $24.00\,(\frac{2}{3})^2$ microhms. The length of the mean turn $= \frac{2}{3}\,(4.5 + 0.85 + 5.4 + 1.65) = 12.4$

Then $t = \dfrac{w^2 l^2 \rho}{2h}$ $\therefore 1 = \dfrac{w^2 \times 10^{-4}\,l^2 \times 2.4 \times 10^{-6} \times 1.46}{2.00 \times 10^{-2}}$

$200 = \dfrac{10^2 \times 1.54 \times 2.4 \times 2.0 \times 10^{-4}}{} = w^2 \times 3.70 \times 10^{-4}$

$w^2 = 10^6 \cdot 3.70 = 270.00$ $w = 520$ say 525

The length of wire is thus 525 × 0.141' = 24 ft = 56' per ~~[illegible]~~ BWG 0.028 covered = 0.0882.

The surface circumference = 7.85 × 3.142 = 24.7 = 7.24". allowing for insulation = 6.5 ÷ 0.028 = 195 wire + 3 deep = 585 wire = 33 wire to each division or 3 layer of 11 × 15 (165) early. = 495 wire.

At 2400 revs. per min = 40 per sec.

$40 \times 500 \times \phi = 7.5 \times 10^8$

$\phi = 7.5 \times 10^1 \div 2 \times 10^4 = 3.75 \times 10^4$

$= 37.500$

ϕ in the armature is $\frac{18750}{2.52} = 4.900$.

The reluctance of the air space is $0.5 \div 2.52 - 6.5 = 0.5 \div 19.4 \times 4.5$

$= 0.5 \div 82.8 = 1 \div 165.6 = 0.0060$ lines, and the mmf required to drive 50.000 lines through this = 300 on each limb.

= 238 AT on each @ 0.25 amp = 952 turns. The p.d. being 7 volts the res. must be 30 ω.

The winding space is $0.785\,(6.3^2 - 3.6^2) \times 6.5 =$

$0.785 \times 26.73 \times 6.5 = 136.4$ c.c.

$$d = -0.02 + \sqrt{0.00004 + 0.00153\sqrt{\frac{136.4}{30}}}$$

$\sqrt{4.547}$

2.13

$+ 0.00326$

$+ \sqrt{0.00366}$

$+ 0.06$

$= 0.0400 = 0.016"$ # 27 BWG. If however as this is found wire the field be in series = 7.50 each.

$d = -0.02 + \sqrt{0.00692}$

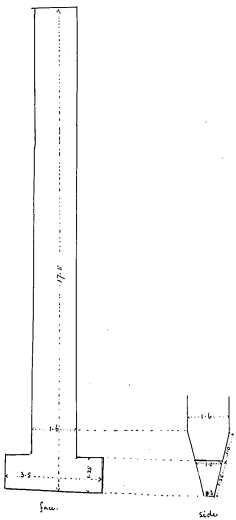
$= -0.02 + 0.083$

$= +0.063 = 0.025"$ = # 23 BWG 0.035" cont.

= 70 turns per layer @ 0.5' per turn. 14 layer = 980 turns = 490'

= 8 ω. 7.5 ω of # 23 @ 0.114' = 0.86 lbs on each limb = 1.72 lbs in all

Solid copper



Coefficient of Expansion of Wax Cylinder or Ring in Phonographic Doll.

23rd Jany. 90. From the means of seven observations, the ring has a diameter of 2·729" @ 66°F

+ 2·717" @ 39°F

0·012" for 27°F = 15°C.

0·0008" " 1°C.

coeff: 0·000298 linear expansion 1°C. between 4°C + 19°C.

On the best winding for an electrically heated copper soldering iron of given dimensions

The surface intended to be exposed is that of the widened part it is $2\{(3{\cdot}5 \times 1{\cdot}25) + (3{\cdot}5 \times 0{\cdot}15) + (0{\cdot}65 \times 1{\cdot}2)\}$

$2\{3{\cdot}5 \times 1{\cdot}4 + 0{\cdot}65 \times 1{\cdot}2\}$

$2(4{\cdot}9 + 0{\cdot}78)$

$2(5{\cdot}68) = 11{\cdot}36$ sq. cms.

The radiation in Watts per sq. cm. from this surface blackened will be $2 \times 0{\cdot}0687\,(1{\cdot}0077^{273} - 1)$

$\log 1{\cdot}0077 = 0{\cdot}0033303$

$\times 273$

$0{\cdot}909090$

$1{\cdot}6667$

$46{\cdot}3$

$2 \times 0{\cdot}0687 \times 46{\cdot}3$

$6{\cdot}23$ Watts.

and for the entire surface 70·7 Watts.

Allowing as great a loss for working purposes + for conduction leakage we have to supply 120 Watts. = 1·2 amperes. from 110 volts = 84·5 ω hot resistance of iron wire.

Siemens gives for iron $r = 0{\cdot}0725445\sqrt{T} + 0{\cdot}0038133\,T - 1{\cdot}2397$

for 20°C $T = 293$ $\quad r_{20} = 0{\cdot}0725445 \times 17{\cdot}1 + 0{\cdot}0038133 \times 293 - 1{\cdot}2397$

600°C $T = 873$ $\quad r_{600} = 0{\cdot}0725445 \times 29{\cdot}5 + 0{\cdot}0038133 \times 873 - 1{\cdot}2397$

$r_{20} = 1{\cdot}2241 + 1{\cdot}12 - 1{\cdot}24$

$r_{600} = 2{\cdot}14 + 3{\cdot}33 - 1{\cdot}24$

$r_{20} = 1{\cdot}12$ $\quad \frac{r_{600}}{r_{20}} = 3{\cdot}44$

$r_{600} = 4{\cdot}23$

The resistance at 20°C required is thus 24·6 ω.

One turn of wire round the copper cylinder over insulation will be about 5·7 cms long. Suppose 100 turns of wire = 570 cms. Then

$\frac{570}{5} / = 24{\cdot}6$ $\quad \therefore / \frac{570 \times 0{\cdot}785}{d^2}(10{\cdot}0) \times 10^{-6} = 24{\cdot}6$

$d^2 = \frac{570 \times 7{\cdot}85 \times 10^{-6}}{24{\cdot}6} = 182 \times 10^{-6} = 1{\cdot}82 \times 10^{-4}$

$d = 1{\cdot}35 \times 10^{-2} = 0{\cdot}0135$ cm.

$= 0{\cdot}0054''$

Experiment on the variation of electrical conductivity of iron under magnetic stress.

Jan. 24th 90. Took a glass tube 10·6 long, and $\left\{\begin{matrix}1.18 \\ 1.0\end{matrix}\right.$ external / internal diameter filled this tube as full as possible with soft iron wire 0·0105" diam (0·026) covered each 0·016" (0·041). The wire was prepared by winding from a spool round two brass pins 10·5 apart, 150 times, thus making 300 lengths of wire in the tube. The resistance of all this wire in one length was about 100 ω. The bight projected about 0·25 from each end of the tube. Insulated copper wire was then tightly wound in 89 turns round the center of the tube. The arrangement was supported horizontally between the poles of the large electromagnet. The effect of exciting the latter with 20 amperes was only to increase the resistance from 98·3 to 98·4 ω. 0·1 %. The deflection from the copper wire tube on the ballistic galv. with 6000 ω in cct. was 75 divs. while 1 co. gave 123 divs: through 0·4014 ϕ. ∴ 1 div represents 4.73×10^{-10} ϕs.

$$75 \text{ " } = \text{ " } \quad 3.55 \times 10^{-8}$$

$$\text{as: in cct. } 11,250 \times 10^{3} = 1.125 \times 10^{13}$$

$$\therefore a = 3.55 \times 10^{-8} \times 1.125 \times 10^{13}$$

$$= 3.99 \times 10^{5}$$

$$\phi = \frac{3.99}{0.89} \times 10^{3} = 4.5 \times 10^{3}$$

$$b = 5700$$

Jan. 25th On the supposition that there might be some leakage between the iron wire through cotton chaffs by abrasion in forcing through glass tube, boiled it in paraffine, cool and then repeated test as follows. Exchanged pole pieces for those ending in conical points which were brought to bear upon the extremities of the tube leaving about 0·25 clearance in all. The resistance with magnet unexcited T.B. 20·6°C 98·420 lead 1·99.

excited from 115 m		98·58 =
unexcited		98·42
Diff.		0·16 = 9643 = 0·8%

On increasing battery power to obtain more accurate reading, the resistance of the coil again became unsteady.

Ballistic throws from external tube on tube

with 7000 ω in cct. res.	12,250 =	·67	8205 000
5000 ω " " "	10,250	87	892 000
" " "	5250	177	929 000
			2641,800
		Mean	880,600

1 b.b 0·4014 ϕ gave mean 131·5 divs

$$\therefore 1.43 \times 10^{8} \times 0.4014 \times 10^{-10} \text{ abs: ϕs represent } 131.5 \text{ divs}$$

$$\therefore 1 \text{ div represents } 4.39 \times 10^{-10} \text{ abs: ϕs.}$$

$$\therefore \phi = 4.39 \times 10^{-10} \times 8.81 \times 10^{14} = \frac{38.7 \times 10^{4}}{89} = 4.35 \times 10^{3}$$

Assuming no flux through glass cotton & airspaces each of the 300 wires carried 1.29×10^{8} lines & the area of each wire = 5.59×10^{-4} sq. cms. ∴ $b = 14.5 \div 5.59 \times 10^{-4} = 259 \times 10^{4} = 25900$

This is the maximum value and the min: value is 5540 per sq. cm

Second approximation

$$D = \left(\frac{1.943 \times 2.3 \times 240}{1.5}\right)^{\frac{1}{2}} \times 10^{-2}$$

$$= (713)^{\frac{1}{2}} \times 10^{-2}$$

$$= 5.17 \times 10^{-2} = 2.035'' \times 10^{-2}$$

$$= 0.020'' \text{ correct} = 0.015'' \text{ uncorrected say } \# 28 \; 0.016''$$

$b = 1'' \div 0.020 = 50$ turns

$\frac{C-c}{2} = 1.5 = 0.6'' = 30$ layers $= 1500$ turns

Mean turn $\frac{\pi\, 16.5'}{30.5} = 1.7' \times 1500 = 2550'$ @ $0.05\frac{1}{2}$ per ft $= 135$ yds

140 yds of #25 B&S (@ 7.43×10^{-3} $= \frac{1558}{1000} \times 10^{-2} = 1.58$ lbs. 1 lbs. 9 oz.

At 30 revs. per sec: The area of the coil $= 1500 \times 3.14 \times 260$

and the emf. $e = 1.5 \times 3.14 \times 2.6 \times 2.0 \times 6.0 \times 10^{-2}$ volts

$= 1.47$ volts.

If the driving handle make 1 turns per second the multiplication must be 40 times, say $(6\frac{1}{2})^2$

From diameter 21' to diam 3"

and again from diam. 10.5" to diam 1.5".

Calculation of the best winding for the Revolving Earth Inductor.

Let the diam: of the first layer or base of ring channel be B. in this case we will assume B to be 15. The area of the winding space cross section $= a$ and B the ext: diam: over wire. Then the breadth of channel being b and ending space c we have

$$K = \frac{b}{4}\pi (B^2 - B^2)$$

$$a = \frac{b}{2}(B - B)$$

The number of turns $w = \frac{K}{\pi D^2}$ where $\tau = \frac{\pi}{2}(B + B)$

$$= \frac{2K}{\pi D^2 (B + B)}$$

The resistance $r = \frac{K\rho_1}{D^4}$

If φ be the resistance of the phone, the emf. generated by the coil making n revolutions per sec:

$$e = H \times \pi\left(\frac{B+B}{2}\right)^2 \times 2n \times w \times 10^{-8}$$

$$= \frac{H \pi n (B+B)^2 K}{\pi D^2 (B+B)} \times 10^{-8}$$

$$= H n \frac{(B+B)}{D^2} K \; 10^{-8} \text{ volts.}$$

The current maximum in the telephone neglecting the effect of inductance is

$$C = \frac{K H n \left(\frac{B+B}{D^2}\right) 10^{-8}}{\frac{K\rho_1}{D^4} + \varphi}$$

$$= \frac{\frac{h}{D^2}}{\frac{l}{D^4} + \varphi} = \frac{h}{D^2} \frac{D^4}{l + \varphi D^4}$$

$$= \frac{h D^2}{l + \varphi D^4} \quad \text{where } h = \frac{K H n (C+c) 10^{-8}}{K\rho_1}$$

$$\frac{dc}{dD} = \frac{2hD(l + \varphi D^4) - 4\varphi D^5 h}{(l + \varphi D^4)^2}$$

$$= \frac{2hD}{l + \varphi D^4} - \frac{4\varphi h D^5}{(l + \varphi D^4)^2}$$

for $\frac{dc}{dD} = 0$ $\quad 2hD(l + \varphi D^4) = 4\varphi h D^5$

$$\therefore h(l + \varphi D^4) = 2\varphi D^4$$

$$D^4(\varphi h - 2\varphi) = -hl$$

$$D^4 = \frac{hl}{\varphi \cancel{(2-h)}}$$

$$D = \sqrt[4]{\frac{l}{\varphi}} \sqrt[4]{\frac{K\rho_1 H n (C+c) 10^{-8}}{K[2 - \varphi H n (C+c) 10^{-8}]}}$$

$$\frac{K\rho_1}{D^4} = \frac{\varphi\,(2-h)\,K\rho_1}{\cancel{h}} = \frac{\varphi\,(2-h)}{\cancel{h}}$$

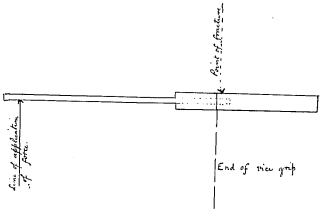
the resistance of the coil must equal that of the telephone + connections, while the telephone itself should have as high a resistance as possible: If $C = 18$, $+ b = 2.5$ Then $K = 194.3$

$$D = \left(\frac{194.3 \times 2300 \times 1.2 \times 10^{-6}}{150}\right)^{\frac{1}{4}}$$

$$= \left(\frac{1.943 \times 2.3 \times 1.20}{1.5}\right)^{\frac{1}{4}} \times 10^{-2}$$

$$= (357.6)^{\frac{1}{4}} \times 10^{-2}$$

$$= 4.35 \times 10^{-2} = 0.0435 = 0.017 \text{ low covering} = 0.010$$



Test of the Transformer #1
after placing in its box beneath the track. 24th Jany. 90.

With 6 volts at low volt terminal, the current to the track was 30 ampères, the day being mild + clear, = 180 Watts. With 20 volts 100 ampères of leakage or 2000 Watts lost power might be expected. This in excess of what was anticipated from the trials made on the laboratory premises with buried single rails.

Test of the Breaking strains of the new Meter zinc plates from samples supplied by Mr. Gladstone 26th Jany. 90.

The zinc plates tested were gripped in a vise so as to lie horizontal, and with the lug free. By means of a connection screw weights were applied at the screw thread near the end of the rod until fracture at the shoulder of the zinc took place. Eight trials were made as follows:-

No. of trial	Breaking weight	Weight of casting	Total breaking wt	Total breaking wt grams	Length of lever	Moment of couple lbs. × grms	Mean breaking wt	Mean breaking couple
1	66	13 lb	79	22400	7·2	16100		
2	68		81	23000	2·9"	16600		
3	112		125	35740		255000		
4	117		130	36900		26600	3280	28,540
5	64		77	21800		15700		
6	159		172	48800		35150		
7	92		105	29800		21500		
8	140		153	43400		31200		
			922	262500		188350		

Test of Car Track resistance when Transformer #1 running

E.M.F. at generator terminals (0·5 33000) = Current 8 amp. Activity.
After this had been applied for about 15 mins the current fell to 2 amp.
During this period the current in the secondary coil must have been about 300 ampères. Probably some screws had been left in accidental contact between center rail and his rod and this became destroyed by the strong current. P.D. at track 20·5 v.
Reduced generator pressure to (2·25 33000) = Current 2 amp activity
P.D. at track close by transformer 15 volts.
Took a res. of lead + ampère meter + coil = 0·135 ω and obtained current of about 110 ampères by transformer. At Tony corner distant 400 feet this current was 90 amp. = 0·158 ω = 0·02 for 400 feet of track = 0·005 ω per 100 feet = 0·00005 ω per ft = 5×10^{-5}
at the cemetery gate the current was 65 ampères = 0·231 ω = 0·096 2200 feet of track = 0·00044 ω per 100 feet = 0·000004 ω per ft = $4 \cdot 4 \times 10^{-5}$
a current of 500 ampères thro' 450 feet = 0·02 ω would drop 10 volts.
Each foot of the center rail without joints being 3 sq. ins. of iron should offer $1 \cdot 17 \times 10^{-5}$ ω. The outside rails offer would offer without joints about the same resistance each = $0 \cdot 59 \times 10^{-5}$ ω in parallel. So without joints the res. of one foot of track would be $1 \cdot 76$ ω $\times 10^{-5}$ instead of $4 \cdot 4 \times 10^{-5}$ 40%.

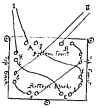


Diagram of connections Astatic Differential Troy Galvr.

On the 25th Mar. 1890 the compensating resistor of 22·6ω was removed and replaced after a refilling of with 31·7ω of double wound 0·002" copper wire. See p. 15 Book 2E

Tests of a certain material named Breslaw Compound for Bergmann &c:

Jan. 28th 90. This sample was in the form of a small disk, black material. It polishes well & apparently pressed used in a mould. is soft, has under this fole the appearance of slate on a fresh surface. It will not support a flame but catches fire in a flame with disengagement of gas, and a smell of burning gelatine. It takes a good shade very easily, but the substance is weak, and brittle.

Samples soaked in water, NH_4, NaO, HCl, H_2SO_4 & behaved badly but pieces exposed to a comparatively high temperature above the boiler 65°C. did not suffer.

Differential Astatic Galvr:

Resistance of individual coils 27. I. 90

A	858ω	B	737ω
C	1010ω	D	1007ω
E	999ω	E	984ω
F	846ω	G	744ω

28. I. 90 { Resistance of complete circuit A D E H I black 36.5 g ω=3 T.B. 23·8°C. T.G. Abt 23°C
, " " " B C F G. II white 36.2 g ω=3 " "

Added a compensating coil of 9·4ω to ⅌ II cct. behind the bof coil to effect the balance ⅌ I being in preponderation, also a spool of 22·6ω resistance in C.S. wire.

Repetition of Experiment on the Saturation of iron by transverse magnetic stress.

Jany. 29th The same box described on page 91 was rewound with 30 turns of silk covered copper wire 0·015" to 0·020" on all four sides. The resistance of each coil was 0·675ω @ 20°C. Preliminary results were obtained when rubber plates 0·198" (0·005) were inserted on each side of box between it and pole faces. The readings were with no current and with 18·37 amperes thro' magnet Saturation same as on previous occasions recorded. T.B. 25·5°C.

No. of Cct.	Direction relatively to magnetic effect	Current thro' magnet coils	res. ind.	leads	res. of coil	Rdg. for balance inf.	Inductance of coil	Res. in bulbs, galvr. cct.	Throw on reversal	φ	L
1	=	0	2·709	2·046	0·663	0·460	12·46	—	—		
2	+	-	2·721	2·046	0·675	0·440	11·97				
3	=	-	2·730		0·684	0·440	12·01				
4	+	-	2·725		0·679	0·425	11·58				
1	=	18·37	2·710		0·664	0·155	4·20	a	35		
2	+		2·722		0·676	0·060	1·63	25000	217·5		
3	=		2·731		0·685	0·160	4·37	0			
4	+		2·726		0·680	0·060	1·63	25000	190.		

1 C.C 1·4223 ω thro 0·40μ + gives 66 divs.

Experiments on the effect of an electric current traversing cotton cloth (thereby) rendering it waterproof. Jan 30th 90

Made a number of miscellaneous experiments following the lines shown by Mr B. Brevoort the day preceding. He showed that piece of cotton cloth dipped in plain water and pressed between tin surfaces became waterproof after a few moments submission to a current from a few cells traversing the cloth in the direction normal to its plane. He stated tin to be the best metal for the purpose, and that the effect was a function of the p.d. current pressure and time employed. There is a slight change of color noticeable in the cloth produced by the operation and drops of water thrown upon it after drying are repelled from its surface and tend to assume the spheroidal state. The electrodes employed by Mr Brevoort were disks of block tin about 4.5 in diam. and 0.5 thick. They were kept clean and plain, were pressed upon the cloth face to face by a hand grip and about 10 volt was the maximum emf employed. The time of current application varied between 5 and 30 seconds. Mr Brevoort said that he had used most metals for electrodes but had failed with platinum. Also that any considerable trace of acid in the water used for wetting the cloth produced failure.

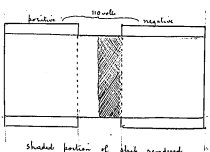
Repeated these experiments with various electrodes and qualities of cotton cloth. Found good results with zinc electrodes ~~but~~ and water but failed with the same electrodes and solution of $ZnSO_4$ as the immersion.

Will fow phy much in water. The action was very powerful at the anode the sheet on that side being markedly waterproof. The succeeding sheets were less so and finally the fourth or cathode sheet was scarcely if at all affected upon. This is in accordance with Mr Brevoorts results which show the oxygen electrode or anode to be the important electrode.

Jan. 31st Succeeded in obtaining the effect with strips of cotton between clamps The strips were about 2.5 broad and their length between clamps 2 to 8. The effect in these cases was observed (with zinc clamps) on the cathode half of side, and also under both clamps. 110 volt was the p.d. in these trials.

Feby. 1st Obtained some results with blotting paper between disks of tin, water immersion, and also some results with strips arranged as in yesterday's experiment with clamps, when soaked in solution of NaCl in H_2O. Failed with dilute H_2SO_4.

Took a strip 3 cms broad and about 7 long. This was moistened in tap-water and then layed across two small metal zinc plates connected with the 110 volt circuit and separated by 1.5cms. No upper plate or pressure was used to keep the strip in contact with these electrodes. The strip was cut diagonally to the mesh. After about three minutes a white line of some salt had formed across the strip parallel to the edge of the electrodes and about midway between them. On drying and immersing the strip, all that portion 0.5×3 on the cathode side of this demarkation line was waterproof, all on the other side being apparently unaltered.



Shaded portion of strip rendered water repellant

Succeeded in a series of twelve trials in obtaining very good waterproofing effects from two disks of blocks 5 in diameter × 0.3 thick, turned true in a lathe + brought smooth with the finest emery powder. The battery was 4 cells of 300 hr NiHO and 6 cells of Burnell's Leclanché in 2 series parallel i.e. 6 × 0.7 + 3 × 1.5 = 4.2 + 4.5 = 8.7 volts. The ammeter was the spring inst. up to 5 amperes. The time of current application was gradually increased with improvement up to 90 seconds commencing at 1 amp. + falling to 0.3. The pressure was 5500 or about 280 per sq. cm.

Repeated the best already recorded of this morning with two strips cut diagonally with the warp + woof. The length were 3 and 2½ respectively between edges of zinc electrode. In each case a white irregular line about midway and parallel to the electrode lines formed after some time. All the surface on the cathode side of this line was repellent more or less all on the anode side (+) was either not deflected or even attractive. Examined this white line under microscope. It appeared to be either due to or accompanied by much destruction of continuity in fibre which on the line seemed to be torn and irregular.

Feby 2nd Made a series of experiments on the effect of time on the production of repellent action employing constant e.m.f. and pressure. With tap water immersion two disks of tin above described, 7 volts + 5500 g. pressure gradually increased the time to 90 seconds at which + interval the best results were obtained. Current 1.4 to 0.4.

Next tried a series at constant time and pressure but varying e.m.f., with 10 seconds application and other conditions the same, found best e.m.f 6.77 volts (about). Reducing gradually lessened effect until with 10.8 volts it was very weak. At this last value however the effect of increasing the time to 60 secs was to make the effect result very good.

Tried the effect of placing a piece of cotton in a bottle exhausting the same and then forcing hydrogen gas through it. No result was obtained by this means when the cotton was put in wet or dry.

Continued experiments with strips lying across electrode using 115 volts. Repellent effects obtained in every case on cathode side extending usually from the electrode over to the demarcation white line usually about half way across. Obtained effect with two arc light carbons as electrodes also on − side. Obtained effect using immersion of solution 100 c.c. tap H.O containing 7 drops HCl conc.

Tried to obtain effects using water electrode. The strip was laid across insulating supports and zinc electrodes placed near its ends but separated by about 0.2. These gaps were filled with tap water. No result was obtained with plain water apparently from want of conduction, but on repeating with dilute acidulated water just mentioned, the result was distinct on the cathode side.

Strips were also tried thoroughly washed in strong HCl to remove the sizing and then washed out in NH_4HO. The conductive power of these strips in tap H.O was apparently very small but using dilute HCl, as above effect was obtained. Passed a current from 115 volts through 2000 and a single thread of cotton on a slide under the microscope. With a magnifying power of 220 no effect or change could be detected.

Armature 96 divs: # 9 B&S. 0.145" wire round in each div.
= 96 complete turns = 192 wires all round armature. Area: 0.040 - 0.055".
= 25 lbs. weight of wire approx. Commutator 96 blocks.

Field winding 63 lbs of # 17 B&S on each spool. 18.7 ω each @ 1.55 ω

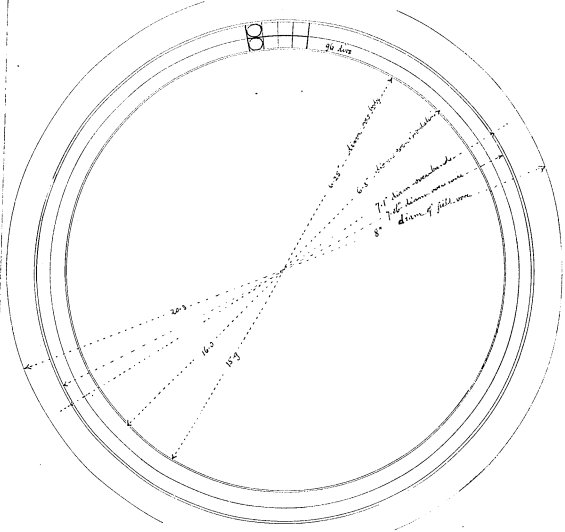
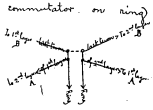


Diagram of commutator or ring disk at back of winding



Calculations for a 50 volt continuous and also alternating current dynamo of No. 14 Standard General Dimensions to utilize the parts that remain available from the Transformer.

The transformer when supplied by 960 volts and operating its own fields in series was made 1500 revs. of its armature, with this additionally large bore we may say 1900. It had 1728 wires on the drum and the flux was therefore

$$\frac{9.60 \times 10^{10}}{1.73 \times 10^{3} \times 3.0 \times 10^{1}} = \frac{9.60}{5.19} \times 10^{1} = 1.85 \times 10^{1} \text{ lines utilized.}$$

For convenience and to have ample margin we may take 1.0×10^{6} as the available flux to produce 50 volts. Then at 14.00 revs:

$$w = \frac{5.0 \times 10^{2}}{2.33 \times 10^{1} \times 1.0 \times 10^{6}} = 215.$$

As there must be employ the 96 bar commutator be either 192 or 288 wires we may take 192 which will represent one complete turn to each division of the commutator.

The circumference over insulation = 19.8" and this after deducting for fibre and insulating paper leaves 17.4" ÷ .96 = 0.181" for the covered wire = # 9 B&S 0.145" allowing for thick wire. The thickness of two such layers will be 0.35" and over bands 0.4", which will make external diameter over bands 7.1", and if fields are unaltered the clearance would be 0.45". # 9 B&S. happens to be the exact size employed with # 14 O.S. machine in 100 complete turns.

By disconnecting the last turn of both layers and reversing them mutually the machine becomes an alternator giving 100 volts at the peak of the wave and $\frac{200}{\pi} = 63.7$ volts mean at $\frac{14.00}{60} = 23.3$ ~ per sec.

The field winding may be the same as that employed for the 125 volt machine except that the magnets will charge themselves at 50 volts in parallel and will be charged in series from the 110 volt set when the dynamo is used as an alternator.

If the field be bored out a few to the same diameter as the ordinary # 14, the voltage will increase to 100 self exciting and the machine becomes practically a O.S. # 14.

Calibration of Obach Single Ring. 7. 12. 89.

Silver Voltameter 25% neutral solution of $AgNO_3$. Plate 9.8 × 3.5
About 2 amperes was passed through this and the ring for 300 seconds. Deflection. 0.385

Weight before test	Anode	Cathode
	16.9287	12.3226
	16.3712	12.9790
	0.5555	0.6564

Mean 0.6560

0.656 ÷ 300 = 0.0021867 gms per sec.
0.0021867 ÷ 0.00118 = 1.956
0.385 ÷ 1.956 = 0.1969 say 0.197

Further experiments on the effect of electric currents traversing cotton cloth thereby rendering it waterproof. cont. from p. 150.

3.II.90 Employing two platinum electrodes repeated experiment of previous day – A short strip of cotton was soaked in conc. HCl for a few minutes. Then washed out and soaked in dil. NH_4HO and then washed out again before immersing (after being dried) in solution of HCl in half water 7 drops in 100 c.c. This strip about 2.5 × 2 was laid horizontally between two parallel edges of non conducting material, bridging them so to speak and the ends of the Pt electrodes brought up to within 0.2 of the ends of strip. The intervening non-conducting spaces were then filled up by a few drops of the dilute HCl and the 110 volts applied. The conduction was apparently very feeble. But in application of 5 to 10 min. results of some interest indicating repellent effects near cathode, and in one instance a solution of madder took depth on the portion of strip, indicating presence of a mordant. The effect however was very feble and manipulating between the fingers was sufficient to extinguish it.

On applying current between lead electrodes for a few moments through a strip moistened in tap water, the rinsing of the strip in solution of $K_2Cr_2O_7$ was to produce evident appearance of $PbCr_2O_7$. No such appearance was produced by mere pressure of wet strip between electrodes without current.

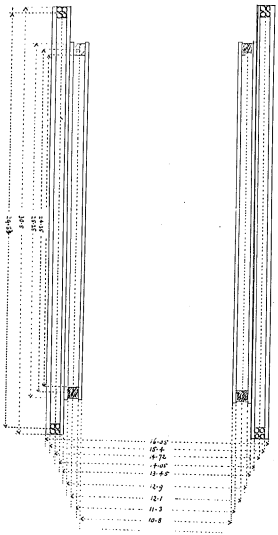
4.II.90 Using lead plates and bridging them with strips moistened in water and very dil. HCl obtained a series of consistent results on dyeing, immersing in $K_2Cr_2O_7$ sol: as follows—

On the + electrode the $PbCr_2O_7$ attached with increasing strength up to the edge from that point it diminished to about 2/4th intervening distance where it nearly disappeared. This gave way to a very distinct bright yellow or brown hydrogen band terminating at the edge of the – electrode and over the – electrode there was no effect.

Between electrodes of platinum using a few volts transversely and moistening with tap-water there was very apparent attraction effect on dyeing, with dyeing action in the case of a mixture of logwood and madder. With carbon plate first on + and then on – side with opposition of platinum partly repulsive and partly attractive effects were obtained.

Current strength available in Galvanometer Room from Low Tension Dynamo.

Joined up the 1500 ampere meter with the large platinoid strip resistance and the Bus bars in galv: room. Obtained a current of 280 ampere with about 5 volts terminal p.d. at dynamo and about 450 ampere - - 8 - - - -



Calculation of the Constants of the Thory Standard Double Coil Galvanometer on last page.

The fundamental equation carried to a first approximation is

$$m l H \sin\theta = \frac{m l n \gamma \cos\theta \times 16\pi}{5\sqrt{5}\,A} = \frac{4.49\, n \gamma \cos\theta}{A}$$

$$\therefore n = \frac{H \tan\theta\, A}{4.49\, \gamma}$$

For the large ring and thick wire 1 amp. ($\gamma = 0.1$) gives 53° of which the tangent is 1.327. Taking H at 0.187

$$n = \frac{0.187 \times 1.327 \times 14.7}{4.49 \times 0.1} = 8.12$$

n may therefore be accepted as 8. i.e. 2 layers on each ring. The ext: diameter being 30.5 and the width of the coil being 0.675 the int: will be 28.150 and the diam: of the mean 28.825. The distance between the mirror planes should be 14.41 and is actually 14.7. Neglecting this error we have accurately

$$H \tan\theta = 8\gamma \left\{ \frac{16\pi}{5\sqrt{5} \times 14.5} \left(1 - \frac{1}{60}\,\frac{0.675 \times 0.675}{14.5 \times 14.5}\right) + \frac{0.0512 \times 3.1416 \times (28.825^2 - 8 - 5)}{3\sqrt{5} \times 14.5^3} \right\}$$

$$\frac{H}{\gamma} \tan\theta = 8 \left\{ \frac{50.2656}{5 \times 2.237 \times 14.5} \left(1 - \frac{3.4556}{12618}\right) + \frac{0.0512 \times 2.237 \times 8.4556}{6.4 \times 10^5} \right\}$$

$$= 8 \left\{ \frac{50.2656}{162.11735} \left(1 - 0.0000036\right) + \frac{0.05224}{0.00064 \times 10^5} \right\}$$

$$= 8 \left\{ 0.31006 \times 0.999964 - 8 \times 10^{-5} \right\}$$

$$= 8 \times 0.31004$$

$$= 2.48032$$

$$\therefore \gamma = \frac{H \tan\theta}{2.48032} \quad \text{or} \quad 0.4032\, H \tan\theta \quad \text{(abs measure)}$$

$$\text{for } H = 0.187 \quad = 7.540 \tan\theta \times 10^{-2} \quad \text{(abs. measure)}$$

For the small rings A is approximately 12.

$$\text{and } n = \frac{0.187 \times 0.095 \times 12}{4.49 \times 0.0001} = \frac{1.87 \times 0.95 \times 1.2 \times 10^{1}}{4.49 \times 10^{-4}} = 475$$

n should be divisible by 30 nearest number is 480 next 450 & 510

If there are 15 layers of 15 turns then n = 450
" " 16 " " 15 " " n = 480
" " 17 " " 15 " " n = 510

mean it may be taken at 24.4 ∴ mean circ = 7.666 = 2.515 ft.

The res: of the fine wire ext: = 51.5 the diam: of the wire is 0.0155

" # 26 B.S. = 24.61 ft per " = 1267′ ÷ 2.515 = 504 turns.
" # 27 B.W. = 24.9 " " " = 1277′ ÷ 2.513 = 508 "

If there were only 16 layers instead of 17 there would be 480 turns and at 2.515 ft = 1207′ ÷ 24.9 = 48.6 " a difference of 2.9 " This is too large an error to be probable. What makes this number 17 more likely is that in order to make the galvanometric constant C_3 remain the breadth : depth :: 31 : 36 if channel for winding no: of turns on one layer should : no of layers :: 31 : 36

∴ no: of turns on one layer should be 15
and according to this ratio with no: of turns = 15
no: of layers should be 17.4

and 17 may have been adopted. In which case

$$\frac{H}{\gamma} \tan\theta = 510 \left\{ \frac{50.2656}{11.185 \times 12.175} \right\}$$

$$= \frac{25635.4656}{136.1774}$$

$$= 188.2505$$

$$\gamma = \frac{H \tan\theta}{188.2505} = 5.312 \times 10^{-3}\, H \tan\theta \quad \text{(abs. mea)}$$

and for H = 0.187

$$\gamma = 9.938 \times 10^{-4} \tan\theta \quad \text{(abs measure)}$$

On the Connections and output of an Alternating current Dynamo on the plan of the 200 ampere Edison Multipolar.

At 1000 revolutions, with all its coils in series the machine should be capable of delivering 1200 volts mean alternating e.m.f. = $\frac{\pi}{2} \times 1200$ or 1890 volts continuous equivalent, and there are 8 sectors = 236 volts per sector, practically double the winding necessary for 115 volts. There will be 4 complete periods per revolution = 4000 periods per min = 66·67~ per second.

Trial of the Rock-Drilling Machine wounded as shewn on page 26. 5th February 1890.

The current supplied to the armature was about 16 amperes and the e.m.f. 62·5 v. res. = 3·9 ω hot. Current in field reckoned at 4 amperes. Total current 20 amp. energy 1250 Watts. Magnet and armature heating excessively.

To measure the work developed by the machine arranged a ballistic pendulum weighing 116 lbs (52600) and of radius 98" (249). The mean thrust of the drill rod was found to produce an excursion of about 9" (22·9). This is equivalent to a lift of 2·1 cms., and the work done 110500 ergs = 108400000 ergs = 10·84 Joules. The machine was found to be capable of producing 180 blows or 360 reciprocations per min. = 6 per second = 65 Watts. The efficiency is thus 0·052. In reality during reciprocation the current flowing through the armature would be diminished but on the other hand the blows at this speed would probably be lighter than when delivered slowly, as a matter of observation they were lighter. Consequently this efficiency is not likely to be far wrong.

With 4 complete turns of wire round the central core the throw of the ballistic galvo was $-160 + 156 = 156$ mean or $\frac{156}{8} = 19{\cdot}75$ divs for a single turn flux with 50,000 in circ. 0·4014 & charged by 1·43 volts or $0{\cdot}578 \times 10^{-7}$ abs. p. gave 70 divs so that 1 div represents $8{\cdot}26 \times 10^{-10}$ p. + 19·75 divs represent $163{\cdot}2 \times 10^{-10}$ or $1{\cdot}632 \times 10^{-8}$ p. $\therefore \Phi = 1{\cdot}632 \times 10^{-8} \times 5{\cdot}53 \times 10^{8}$

$= 9{\cdot}024 \times 10^{5}$

The diam of the central core round which the wire is wound, is 3·42" = 8·69 cms. an area of 58·6 sq. cms so that

$$L = \frac{9{\cdot}024 \times 10^{5}}{5{\cdot}86 \times 10^{1}} = 15{,}400.$$

Measurement by Cathetometer of the Diameter of a steel Disk at 16°C 7th February 1890.

Upper limit	72·017	72·020	72·024
Lower "	62·326	62·324	62·316
Weight	(3) 9·691	(3) 9·696	(1) 9·708

$3 \times 9{\cdot}691 = 29{\cdot}073$
$3 \times 9{\cdot}696 = 29{\cdot}088$
$1 \times 9{\cdot}708 = 9{\cdot}708$
$9 \mid 67{\cdot}869$
$9{\cdot}696$

The diameter of a disk 12" in diam = 9·702 cms.
9·696
0·006

0·006 cms = 0·0024 deficiency.

Calculation of the Copper Required to Transmit power on the 3 wire system to 20,000 lamps from Canal St. to Fulton St. N.Y. a distance of 4200 feet by a feeder or feeders with 15 % drop on the same.

The current to supply each lamp will be 0.4 ampere and the p.d. at the lamp will be 120 volts @ 1% drop in the mains this will be 121.2 say 121.5 volts at feeder extremities & at 15% this will be 143 volts at feeding two bars, a fall of 21.5 =

The current will be 10,000 × 0.4 = 4000 amperes on the outside. Then r = 21.5/4000

= $\frac{1}{200}$ th of 1 ω roughly 0.005375 ω

= $\frac{1}{840000}$ ω per ft

= ~~0.0000~~ 1.256×10^{-6} ω per ft.

1 c. mil foot has 10 ω.

~~1.~~ 8,400,000 mils will be needed.

the weight of this is 8.4 × 3.0 = 25.2 lbs per foot for +

= 25.2 . . . . –

30% = 7.6 . . . . o

80.0 . . . for all

The total weight would be 240,000 lbs. or 120 tons

Test of some short lengths of Johnson tubing for Conductors, made at Mr S. H. Johnson's instance

A series of different samples of tubing made from paper soaked and hardened in some special liquid was brought to the Laboratory on the 13th January.

These tubes were cut into convenient lengths and soaked in water. Each was closed at both ends with a cork well luted with paraffine wax and filled with common tap-water. A g.p. covered wire was tightly through one cork and gave electrical communication with the interior. The tubes were then left in a stoneware tank full of water.

On the 6th of February one of these tubes gave the following test.

Length 21" (53) Weight 93 grammes
Diam. int: 5/8" 1.56
ext: 13/16 2.0

Constant. Ballistic galv. 1 Ayrton, 450,000 ω. S. 591 ω. 100 divs.
Galv 5300 ω
Shunt 591 ω.

$\frac{9+5}{3} = \frac{5891}{591} = 9.97$

9.97 × 30 × 100 = 29900.

Deflection on sample 30 Ayrton no S. 117 divs.

$R = \frac{29900 \times 0.45}{117} = 115\ \Omega$ abs.

or about 40,000 ω per mile.

Test of the Sewing Machine wound as calculated on page 142 with the battery altered as there described.

7th Feby. 90.

10 Phonograph K.HO 300 amp. hr. cells were prepared specially at Silvertown with double copper and triple zinc plates, thus doubling the active surface in each cell.

EMF of 10 cells 7.35 v. Res: of field 3.4 w. Res. of arm. 0.33 w. Res. of battery 0.33 w. (0.234 v.)

No. of hist.	Condition of motor	P.D. at M.T.	Current in ct.	Current in field	Current in armature	Power in ct. in watts	Power lost in field	Power lost in armature	Power developed in arm.	% eff.	Armature Speed in revs. per min.	Field of pole tips in lines per sq. cm.	Power of magnet in watts	Volts per turn
1	Normal	4.92	4.29	1.45	3.04	10.9	7.14	3.8	11.9	0.53	465	2.43	872	1.01
2	Connected but open circuit	4.05	6.63	1.19	5.44	21.9	4.8	9.9	12.2	0.31	288	3.20	570	1.81
3	2 flys. on	4.05	6.63	1.19	5.44	21.9	4.8	9.9	12.2	0.31	265	3.20	498	1.81
4	4 flys. on	4.09	7.14	1.20	5.94	23.3	4.9	11.8	12.5	0.29	264	3.26	449.5	1.95

Res. of galvo + leads 0.02 w. avg. vol: ratio of sewing machine shaft to motor shaft 1.875

No. of hist.	Power in Circuit	E.M.F.	Power in mot.	P.D. at M.T.	Power in arm.	Armature emf.	Speed rev. per min.	Calculated speed rev. per min.	% eff. induction				
1	33.0	7.35	22.1	4.92	11.9	3.91	7.75		0.54				
2	48.7		26.9	4.05	12.2	2.24	4.8	4.4	0.45				
3	48.7		26.9	4.05	12.2	2.24	4.4	4.4	0.45				
4	52.5		29.2	4.09	12.5	2.11	4.4	4.2	0.43				

Test of Inductance of Phonoplex Receivers

No.	Saw	Phone	Bridge	Res.	Capy	Inductances Seconds	Inductances Kilometers.
1	In	(Ordinary)	1000/10	99.98	0.80	0.0798	798
2	Out				7.337	0.1336	1336
3	In	Special with laminated magnet core		96.19	0.70	0.0673	673
4	Out				1.208	0.1162	1162

Test of the original Schenectady Standard Condenser ½ ϕ by Elliott Bros, after overhaul + resetting.

When still hot from molten paraffine wax 0.3907 ϕ

After cooling down to about 20°C. 0.4157 ϕ.

On the 20th February 1890 by comparison with Elliott Bros: divided unit $\frac{1000}{1110}$ resistance 0.417 ϕ reversing bridge arms 0.4157 ϕ 0.005 ϕ difference balance at about 100 revs per min of handle slow speed by about 2 divs.

Mean capacity 0.4175 ϕ

Data concerning the new Edison Composition Electric Lamp at 18 per h.p. elect.

18 16 c.p. lamps = 288 lamps for 746 Watts = 2.59 W. per c.p.
at 120 volts = 6.216 amperes for 18 lamps = 0.345 amp. each.
The resistance of each lamp (hot) would be = 348 ω
The life of that lamp would be about 900 hours.

The old lamp had 15 lamps of 16 c.p. = 240 c.p. per h.p.
= 3.11 Watts per c.p., the resistance hot was 243 ω and
the current 0.452 amp. at 110 volts
Bamboo filament.

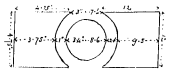
There is also a brand of composition lamp marked Edison #20 which tested as follows:—
125 volts amperes 0.3 per lamp = 319.3 c.p. per h.p. or 19.95
lamps of 16 c.p. per h.p. = 2.34 W. per c.p.
Average life 832 hours. Res. hot 419 ω.
This lamp is at present in reserve.

Test of a sample of insulating material for Messrs Bergmann & Co. N.Y.

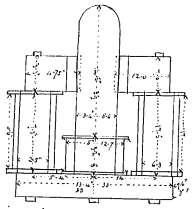
Received two moulded samples one black the other red and spangled, of a substance named Electroid.
It burns very much like Breslaw compound is very weak & brittle does not nourish a flame, and smells when burning like sealing wax. The substance immediately surrounding the burning portion is soft and plastic. It takes a very poor thread but polishes well.
Samples were immersed and tested in the usual manner

Once in plain water	Apparently not much hurt	
" " dil. NH_4HO	This slightly darkened	
" " - H_2SO_4 sp.	Apparently unaltered	
" fused in wet sand	" "	slightly more brittle
" in kerosene oil	" "	"
" over boiler @ 150°F	" "	"

The plastic condition is reached about 300°F (149°C)

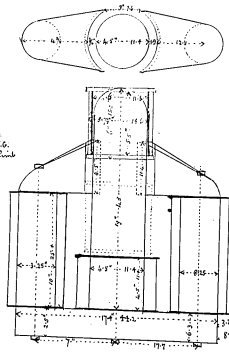


Section at right angle to axis through poles.



Section in plane through three axes.

Section of existing magnets 1/6 actual size.



Magnets
15 lbs 2 oz. of #16 magnet B.W.G.
S.C.C. wire on both each limb
68½ lbs. in all
On outside core ¾" depth
8½ layer of 130 turns
= 1130 turns = 5700 A.T.
On inside core 1" depth
14 layers of 50 turns
= 700 turns = 3570 A.T.
Total A.T. in each half of circuit 9270.

Section of proposed magnets 1/6

Electrical Design of the Rock-Drill Machine as modified from that given on page 26 the test of which is recorded on page 154.

(158)

The existing apparatus has a central core 3" in diam: and outside core 2½" in diam. To obtain greater power these may be increased to 4"·5 and 3·5" respectively (10·5 and 8·9). The present length of outside core is 7" (17·8). This may be lengthened to 10".

The present outside cores have 10 layers of 120 turns = 1200 turns on the outer inside the layers of 141 turns = 570 turns.

The surface of the new outside cores will be approx: 34 × 25·4 = 850 sq. cms and allowing 10 sq. cms per Watt = 85 Watts each. The circumference of the pole space is about 4·7 cms − 15 = 32 = 16 cms. for each face × 11·4 . 182·4 sq. cms. The reluctance of this is $\frac{240}{8.9} \times \frac{1.9}{200} = 0.0095$ lines. The area of the central core is 102 sq. cms and at 18000 lines = 1,840,000 in all or 920,000 to be generated by each limb.

$\therefore \quad mmf = 9.20 \times 10^5 \times 0.095 \times 10^{-8} = 8.74 \times 10^3$

$\text{a.t.} = 6.95 \times 10^3$ say 7000.

At 50 volts terminal p.d. 1·7 amperes will be required limit for heat and the number of turns = 4120.

The resistance will be 50/1·7 = 30 ω hot = 25 ω cool.

coiling space allowing ¾" (1·9) depth of coil = $2.5 \times 0.785 \times (12.7 - 8.3)$

$19.6 \times (146 - 68.9) = 19.6 \times 77.1 = 1510$ a.c.

$d = -0.02 \pm \sqrt{0.0004 + 0.00153\sqrt{\frac{1510}{25}}}$

$0.00153\sqrt{60.4}$

0.00153×7.77

0.01189

$0.01229 \qquad 1.229 \times 10^{-2}$

1.109×10^{-1}

$= -0.02 + 0.111$

$= 0.091$ cms $= 0.036''$ = #19. B.S. @ 125' per ω

= 3110 feet. The mean turn = 4" = 1' roughly ∴ 3110' are about 3100 turns.

The coiling space of the central core is $0.785 \times 11.4 \times (26.9 - 12.0)$ allowing 25%

$= 0.785 \times 11.4 \times 13.9 = 12.25$ ...

The total magnet coiling space is therefore 2 (1510) + 1225 = 4265

Taking the coiling space on each limb as 1500 a.c., and putting the magnets in series, the p.d. on each is 50/2 = 18·67

The current for 55 Watts is 5·4 amperes so that the res: = $\frac{18.67}{5.4}$ = 3·27ω

For this result $d = -0.02 \pm \sqrt{0.0004 + 0.00153\sqrt{\frac{1510}{3.27}}}$ = 2d $\sqrt{\frac{1510}{3.27}}$

$\sqrt{462} \qquad \sqrt{521}$

21·5 22·8

$+ \; 0.0329 \qquad 0.0349$

$\sqrt{0.0333} = \sqrt{3.33 \times 10^{-2}} \qquad 0.0353$

$= 1.825 \times 10^{-1} \qquad 1.879$

$= 0.1925 \qquad 0.1879$

$= 0.163$ cm $= 0.064''$ #14 B.S. $\qquad 0.169$ cm $\quad 0.066''$ #16 B.W.G.

3·27ω @ 5·4 = 17·68 lbs = 145·5 lbs in all

2·9 ω @ 5·234 = 15·18 lbs = 125·5 lbs in all

15·15 × 7·19 ft per lb = 1187 ft = 1100 turns or 5600 a.t.

The no: of turns in 1 layer on outside core = 9·8 ÷ 0·075 = 130 the mean turn has a diam: of 1·05" = 137' per layer = 8½ layers = 0·7" diaf.

The no: of turns in 1 layer on inside core = 4 ÷ 0·075 = 53 the mean turn has a diam: of 1·6" = 168' per layer = 14 layers = 1·0" diaf = 740 turns

The armature will have a surface of about $3.14 \times 14.6 \times 14 = 640$ sq. cms. and at 5 sq. cms per Watt = 128 Watts, = 42.6 amp. @ 50 volts. 4 amperes will however in spite of the heat be necessary = 12.5 w. The breadth of the winding space is 5.5" 3/4 in. of which 3.7" can be utilized. If 3/4" be the enlarge, the clearance 0.05" on interior and 0.13" exterior = 0.18" leaving 0.37" for wire and cylinder. Allowing 0.17" for cylinder leaves 0.14" for winding space. The coiling space is thus

$$0.785\,(12.6^2 + 14.6^2)\,9.3 = 0.785 \times 9.3 \times (213 - 159) = 0.785 \times 9.3 \times 54 = 394$$

$$d = -0.02 + \sqrt{0.0004 + 0.00153\sqrt{\frac{394}{10}}} \quad \text{(bde)}$$

$$394 \quad 9.4 \quad 6.28$$

$$+ \; 0.00061$$

$$0.0400 = 1.0 \times 10^{-2} = 0.1 \text{ cm.}$$

$$= 0.08 \text{ cm.}$$

$$= 0.032'' = \#21 \text{ B.W.G.} = 0.0444'' \text{ covered.}$$

$$= 120 \text{ turns per layer.}$$

$$= 999 \text{ sq. } 1000 \text{ ft. The mean turn will be } 1.4 \text{ ft}$$

$$= 700 \text{ turns} \times 4 = 2800 \text{ A.T.}$$

10 w of #21 B.W.G. @ 0.307 lbs per = 3.07 lbs.

Determination of the winding for the Siemens alternator to deliver 1000 volts

As there are 8 poles there are 4 complete periods per rev: so that at 1500 revs. per min there are 100 ~. The machine gives normally 200 v. at that speed from coils of 16 turns 11 layers deep = 176 turns ∴ for 1000 volts 880 turns are needed. If n turns be in the layer the no: of layers should be $\frac{n}{16}n^2$ ∴ $\frac{n}{16}n^2 = 880$ or $n^2 = 1250$ $n = 36$. and layers 24. The breadth of the coil is 1.6" ∴ $\frac{1.6}{36} = 0.0444''$ covered = 0.032" copper wire = No. 21 B.W.G. D.C.C.

As this wire can scarcely be expected to carry 10 amperes it will be necessary to encroach upon the field. If 3 wires be employed their diameter covered will be 0.066" = 0.052" = #16 B.W.G. and double field will be needed. 16 layers + 24 turns per layer. ~~If 3 wires be~~ The weight of wire on each ~~spl~~ is at present about 7½ lbs = 60 lbs for the whole armature and with the new wire the weight will be a little less = 3 w per coil = 24 w per no: of machine.

In order to improve the existing apparatus the polar heads may be extended to 6" face, and the entrefer reduced to 0.75". The armature will be 7" long (17.5) and its bear diam 3.6" (9.2). The diam: of the polar bore 4.9" and of the external armature 4.7" = 12.0 ∴ the coiling space will be

$$0.785 \times (12^2 - 9.2^2) \times 17.5 = 0.785\,(144 - 84.6) \times 17.5 = 0.785 \times 17.5 \times 59.4$$

$$= 816 \text{ c.c.}$$

The resistance should be about 10 w

$$d = -0.02 + \sqrt{0.0004 + 0.00153\sqrt{\frac{816}{10}}}$$

$$816 \quad 9.03$$

$$0.04392$$

$$0.0442 = 4.42 \times 10^{-2}$$

$$= 4.42 \times 10^{-2} = 0.0400 \text{ cm.}$$

$$= 0.040'' = \#19 \text{ B.W.G.} \quad 0.052'' \text{ cov.}$$

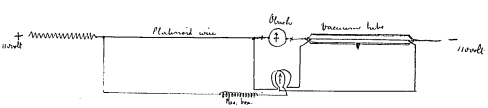
10 w @ 0.31 lbs. per w = 9.4 lbs.

The depth of winding will be 1.4 cm = 0.55" = 10 layers.

The mean turn = 10.6 cm = 4.3" → 13.5" circ. = 1.1'

120 turns per layer = 132' + 1200 turns = 1320' × 5.55 × 10⁻³ = 7.7

15 lb = 45½ in. = 8½ = 1 lb. 14 = The a



$22.4 - 15.5 = 6.9 \times 0.03 = 0.207 = 1.00207$

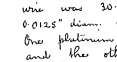
$\frac{4194 + 3718}{3718} \times 1.00207 = \frac{7912}{3718} \times 1.00207 = 2.1324\,\omega$ @ 25°C

Platinoid wire between offsets.

Experiments on the Conductance of Copper at different temperatures.

Febry. 11th. With Fessenden.

Took a glass tube of 2 cms. ext. diam. and 30 cms long, closed at each end, exhausted, and supporting a fine copper wire (bare) diam. 0.002", in its axis. The length of this wire was 30.5 approx. and it was heated with a platinum wire 0.0125" diam. & 2 cms long in glass thus



One platinum wire carried the current and the other served as a pressure wire for carrying back the p.d. to a galvanometer. The object of the experiment is to ascertain the temp. coeff. of copper beyond dispute and also the temperature of first luminosity. The measurements made can only determine one when the other is known but from such data as are already in existence or may be by us determined the results may throw light on both.

The current was supplied from the 110 volt circuit and was regulated by a fine wire res. box. It was found that about 1.25 amperes had to be passed through the wire in the vacuum tube in order to bring it to first luminosity. The tube was supported horizontally near its end in the photometer and the temperature at the commencement of the experiment was 26.6°C as shown by a normal thermometer supported close to it in air. The Edelmann differential galvanometer was used 4.5 volts on its coils in series giving about 0.5 div. Its resistance by bridge was $\frac{1000}{1000}$ T.B. 25.2°C. 5475 ω both coils.

$\frac{19}{6 \times 55 \times 0.03}$ 10 ω temp wr. $= \frac{5475}{2} = 2742\,\omega$ coil

When a feeble current of about 0.1 or 0.15 amp. passed through the circuit balance was obtained with 8290 ω in the standard res. cct. This standard was a platinoid wire 70 long and 0.066 (.002) in diam. on which two pressure wires were soldered 64.5 cms apart. The resistance of this wire wound in a helix was subsequently found to be 2.13 ω. The above balance was obtained with a potential deflection of ± 102 div and 0.5 div. could have been appreciated. It is probable however that this measuring current itself raised the temperature of the wire above 26.6°C, and steps will be necessary in future to avoid this source of error.

By several trials it was found that at first visible luminosity the balance was just 1520 ω. The increase of res. was thus in the ratio $\frac{2738 + 8290}{2738 + 1520} = \frac{10968}{4258}$ $= 2.576$ from the temp. of first measurement something above 26.6°C to the temp. of first noticed luminosity.

The room was dark during these experiments. The shutter all closed and all lamps extinguished in one instance, one covered lit in others.

Febry. 15th. Measured res. of platinoid standard with the aid of astatic differential galvanometer and Elliott 1 ω. Res. of galv. both coils in opposition $\frac{1000}{1000}$ T.B. 27°C 7436 = ords. Balance between 1 ω @ 22.2°C in H.O bath, wire when latter had 4192 ω in its coil cct.

$\frac{9.105 \times 2.132}{2.710} = 7.162 \;/\; 2.4144 = 2.968 \qquad 1.968/.006 = 4814.8°\,C.$

$\frac{9.045 \times 2.132}{2.710} = 7.151 \;/\; 2.4144 = 2.961 \qquad 1.961/.006 = 4841.0°\,C.$

$$\begin{array}{lcl} 2.636 & \text{Wt } 3 & = \quad 7.908 \\ 2.652 & \cdot\ 1 & = \quad 2.652 \\ \hline & & \quad 10.560 \\ & & \quad 2.640 \end{array}$$

$1 + D \cdot 0.004406 \times 23 = x$

$\frac{1.0938}{1.0938} = 2.644 \qquad \frac{7.191}{2.4144} = 2.979 \qquad \frac{7.2445}{2.4144} = 3.000$

$\frac{2.001}{.006} = 4937\,C$

$1 + 0.004406\,x = 2.979$

$0.004406\,x = 1.979$

$x = 4487.5°\,C.$

Res. of wire being 2.64 ω at 28° C taking the coeff for temp. as 0.388%

$x(1 + 23 \times 0.00388) = 2.64$

$x(1 + 0.08924) = 2.64$

$x = 2.64 / 1.08924$

$= 2.4244\,\omega$ res. @ 0°C

The results at first visible radiance were

				ω^2
7.158	Wt 2	.316	6.033	9.9×10^{-2} 19.8
7.160	· 3	.480	0.030	9.0×10^{-2} 27.0
7.245	· 3	.735	0.0825	29.2×10^{-2} 87.6
		1.531		136.4×10^{-2}
		.191		

$0.67145 \sqrt{\frac{134.4}{8 \times 7}} \times 10^{-2}$

$= 0.1686 \times 11.59 \times 10^{-2} =$

$= 0.1686 \times 1.159 \times 10^{-2}$

$= 1.954 \times 10^{-2}$

$= 0.0195 \qquad 0.02$

res. at first visible radiance $= 7.191 \pm 0.02$

Ratio $\frac{R_{vis}}{R_{0°C}} = \frac{7.191}{2.4244} = 2.967.$

Experiments on the conductance of copper at temperature of first visible luminosity. ente from preceding page

15th February 1890.

21.00 Res. of both coils astatic diff. galvo. 7320 ω @ 23°C T.B. Temp. room air 23°

. . . . Edelmann . 5412 ω . . . .

Temp. of air near tube in photometer case 23.1°C.

Dimensions of this tube as near one as follows:—

Length end to end 34.5. ext. diam. 2.1. Length of wire between supports 30.4 cms. Wire copper 0.0015" diam. that had been covered with silk at Schenectady but here dissolved of its covering. Portions of wire were closely axial in tube. When luminous the wire dropped heavily at each end and may actually have touched the glass.

It was ascertained that a current of 0.36 amp. through this wire rendered it just luminous, by one observation of Black. (0.072 cm)

When cool 8.65 ω added to wire balanced the 2.132 ω of standard platinoid res. on astatic diff. galvo. with feeble current diff. 165 ± reading to 10. Res. of wire cool (23°C or closely thereabouts) $= \frac{2.132 \times 4525}{3660} = 2.636\,\omega$

On the d.b. galvo. balance was obtained with 660 ω added to tube deflection ± 92.

$= \frac{2.132 \times 3366}{2710} = 2.652\,\omega$

The wire was then brought up with all lights in the room extinguished to first visible radiance by passing current from the 3.5 volt dynamo in series with 4 Leclanché cells (2.8 v) or about 6.3 volts in all through tube, standard res., galvo. and a platinoid wire with sliding contact. End of wire watched.

Results for balance with d.b. galvo. were as follows:—

Observer at galvo.	Observer at Photometer	Balance	Res. galvo. etc			
H	F.	6610	9320	(1)	9320	
		6400	9110	(2)	18220	
		6320	9030	(3)	27090	
F	H	6365	9055	(4)	9055	
		6465	9175	(5)	9175	
		6365	9075	(6)	18150	
				10	98010	
					9101	

Mean res. hot $\frac{9100 \times 2432}{2710} = 7.158\,\omega.$

Ratio $\frac{R_{hot}}{R_{0°C}} = \frac{7.158}{2.644} = 2.711$

The cooling seemed to take place very rapidly during the first few moments but a long time appeared to be required to reduce the last few degrees of temperature elevation.

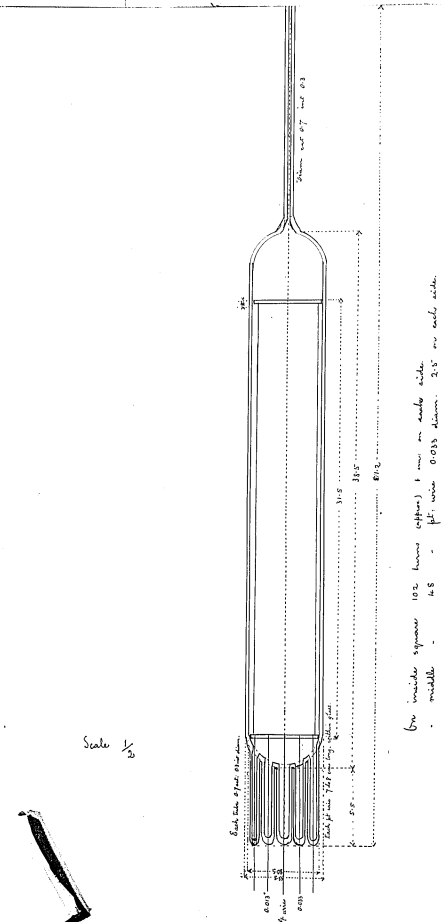
Made sensibility of astatic nearly 5 times greater by controlling magnetic system, and some 30 mins. after taking the res. hot observed Balance on astatic galvo. 1.06 g. 3.6 cm R. $\frac{2.132 \times 4730}{3660} = 2.756\,\omega.$

. Edelmann . 500 ω + 3.6 cm R. $\frac{2.132 \times 3510}{2710} = 2.762\,\omega$

Wire was then brought up to just visible radiance with following results all lights in room extinguished. Centre of wire kept watchful.

No.	Observer at Galvo.	Observer at tube.	Balance	Weights altered by observer	Res. in galvo. etc.	Wt × Res.	Res. of wire	Ratio $\frac{R_{vis}}{R_{0°C}}$
1	H	F	6660	(1)	9370	9370	$\frac{2.732 \times 9269}{2710}$	
2			6555	(1)	9265	27795		
3			6500	(2)	9210	46050		2.744
4			6640	(2)	9350	46750	7.245 ω	
5			6450	(2)	9160	73280		
6	F	H	6700	(1)	9410	9410		
7			6400	(3)	9100	18200		
8			6300	(3)	9000	27000		
				28	9265	257855		
						9209		

Mean


Scale 1/20
Platinum wire 0.5" long 0.03
Platinum wire 0.5" long 0.03
Platinum wire 7.5" long 0.03
Platinum wire 7.5" long 0.03
Platinum wire 7

Res. of G. 5250 ω

75.4 divs given for 5.975 × 10⁻⁸ at 40

1 ω = 7.924 × 10⁻¹¹

105,250 ω = 1.0525 × 10⁻⁶

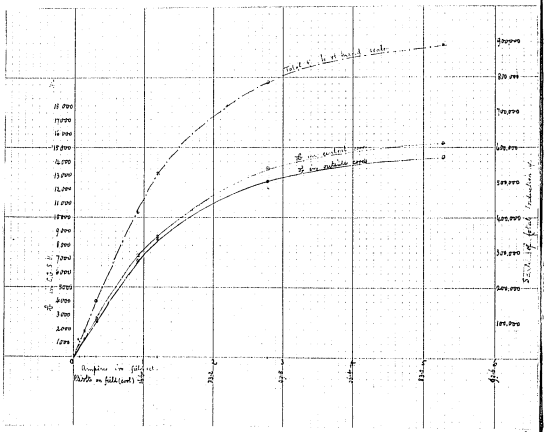
"Diam." of centre core 8.6 area 58.09

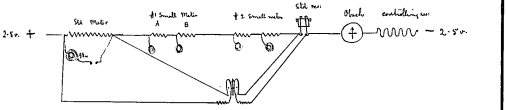
" " outside " 6.3 " 31.17 × 2 = 62.34

Turns on outside cores 113 × 110 = 12,65

" " inside " about 800 085

19,900 × 1.257 = 2390





$\frac{23}{\frac{1}{9}} \times 0.03 = 0.27$

∴ 041.0027 Lw.

$\frac{0.009833 \times 2735.5}{2716} = 0.009942$

$\frac{0.009833 \times 2753.5}{2716} = 0.009997$

$\frac{0.009833 \times 2728.5}{2716} = 0.009906$

$\frac{0.009833 \times 2741.5}{2716} = 0.009953$

Magnetic Characteristic of Rock Drill Apparatus. Febry 28th 90.

The machine is in the condition represented on page 158 with the polar heads shown in red ink. The following observations were taken with 5 turns of twist wire layed closely round the middle core the center of the band being abt 12 from the yoke and being about 3 wide. The current was reversed through the cores, so that a single induction = ½ the observed induction. The three limbs were in series the two outside poles of same name and the inside of opposite name.

Obs. No.	Check Amp	Amperes	No. of Rev. Shunt	Mean	Res. in cir.	Total res. of Galvo. cir.	φ	φ	½ on outside core	½ on outside cores	M.M.F.
1	1.014	5.224	3	107	100,000	105250	8.478×10^{-8}	5.92×10^{-8}	1.576×10^{-6}	1.431×10^{-6}	1.262×10^{-6}
2	0.584	2.78	3	94	.		7.408	7.82	1.35	1.26	6.612×10^{4}
3	0.236	1.20	5	63	.		4.994	5.26	0.598×10^{-8}	8.612×10^{-8}	2.57
4	0.179	0.91	5	51.2	.		4.057	4.27	7.35	6.85	2.18
5	–		3	174	25000	30250	1.379×10^{-7}	4.17	7.18	6.69	
6	0.065	0.33	3	66.5	"		5.269×10^{-8}	1.59	2.74	2.55	7.89×10^{4}
7	0.032	0.163	5	30.6	"		2.425	0.734	1.26	1.18	
8	12.* ×	0.1603	16	177	0	5250	1.102×10^{-8}	0.736	1.27	1.18	3.85
9	7.356	0.0991	2	116.5	0		9.23×10^{-9}	0.408	8.35×10^{-8}	7.78×10^{-8}	2.37
10	1.431	note C.C. @ 21°C	8	754	–	0.4475^{-8}	5.975×10^{-8}				

* Standard galvo.

Res. of the three core windings in series 16.6 ω coil.

Test of meters before experimental use.

Standard 0.1 – 100 ω meter made at Laboratory 1888.

Found one clip on strip indecent, readjusted it.

Res. of shunt by ballistic actuate galvo. diff. res. both coils 743 Ω – $\frac{1000}{1000}$ no. 5. T.B. 23°C T.G. 23°C. = 2716.5 ω each set of coils.

5 volt dynamo current. Connections as shown opposite

Standard copy of 0.1 legal ω correct at 14°C. Temp. of Std 23° = 0.10037

27 ω added to Std for balance = $\frac{1.00027 \times 10^{-1} \times 27\,16.5}{2743}$ = 0.09983 ω = 0.8°C

easily adjustable to 1%

Res. of spool 98.05 ω with its connections @ 21°C.

Current 1.5 amps through main cct.

100,000 ω in cct. with galvo. gives 270 divs ∴ $\frac{270 \times 102,720}{2720}$ = 10,000 divs

approx. would be obtained with one res. alone.

#1 Small meter by Bergmann compared with 0.01 ω copy = 0.009831 @ 23.5°

A side 27 ω added to strip = 0.009942 ω

B " 37 ω " " " = 0.009997 ω

#2 " " " A " 12 ω " " " = 0.009906 ω

B " 25 ω " " " = 0.009953 ω

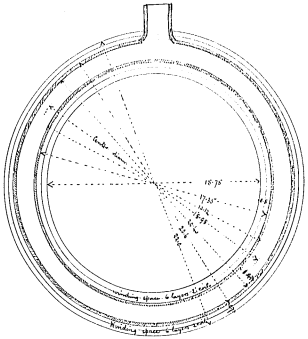
Spools #1 " " " A " 8.045 ω @ 22°C

B " 8.125 ω "

" #2 " " " A " 8.075 ω "

B " 8.075 ω "

Section scale ½ of ring in plane through centre of tube and perpendicular to axis of ring



If O be the centre (of symmetry) of the
X and Y the rectangular axes,
R the int. radius of the ring
a " " axis of tube
Then y the coordinate of any point on the
circumference is $R \pm \sqrt{\rho^2 - x^2}$ where $\rho = R - r$
The volume of the tube on any lamina
comprised between planes through x and x+
$\int dx \, 2\pi \, R + \sqrt{\rho^2 - x^2}$
$4\pi R + \sqrt{\rho^2 - x^2} \, dx$
and this must be integrated from x = ±ρ to
$u = R \int_{-\rho}^{\rho} \sqrt{\rho^2 - x^2} \, dx$

$= \frac{4\pi R}{2} \pi \rho^2 = 2\pi^2 R \rho^2$

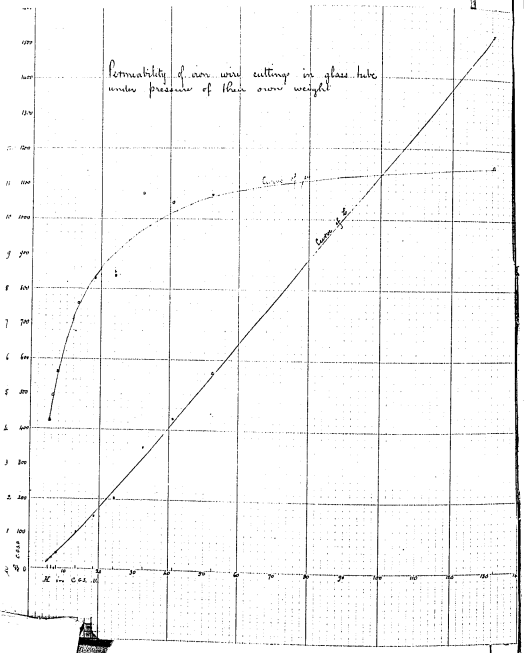
$R = 0.449$
$2\pi^2 R = 187.325$
$\therefore \rho^2 = \frac{100}{187.325} = 0.5349814$

$\rho = 0.7415$

$2\rho = 1.4830$
$2\rho + 2t = 1.6250$
0.142
$t = 0.071$

Let h = cylinder area
a = area of inside tube
$\phi = a\mathfrak{t} + (h-a)h$
when $\phi = Ah = n\,ah$
$\therefore \phi = a\mathfrak{t} + (n-1)ah$
$= n\rho h + (n-1)ah$
$= ah(n + n - 1)$
$\mathfrak{t} = \frac{h(2n-1)}{a}$

$\mu = \mu - (n-1)$
$= 5.20$



1164

Particulars of a Faraday Ring of glass tube for investigating the permeability of liquids and powders.

Ext. diam. of anchor ring of glass tube 20.6
Int. " " " " 17.35
Ext. " " glass tube itself 1.625
Int. " " " " 1.480 by calculation from measurement

This anchor ring has a neck for filling it. The neck occupies an angular distance of about . Two coils each of three layers or six layers in all are wound on the ring. The first layer has 516 turns
" 2nd " " 488 " 25
" 3rd " " 476 " 24
1480 . in first coil
" 4th " " 460 " 24
" 5th " " 456 " 23
" 6th " " 441 " 22
1357 . in second coil.

Res. of primary coil 4.28 ω @ 23°C
" secondary " 5.16 ω @ 23°C

Contents of tube 103 c.c.

The tube was filled to the base of the neck with very short lengths of soft iron wire 0.06 diam. the lengths being about 0.1, or a little less. The weight of these cuttings was 4.67 grammes. The following observations were then made upon the permeability. Current measured.

No. of Obs.	Deflect. obtd.	Current amp.	No. of Bunsen elements	Mean	Res. in cct.	Total res. of galv. cct.	q	φ	$\mathcal{L}$	M.M.S.	μ	Mean μ	Corr. μ
1	12°.45′.0	0.1706	3	31.8	0	5.280	3.528×10^{-3}	1.259×10^{-3}	2.90×10^{-3}	5.32×10^{-3}	5.145	2.24	4.25
2	14°.45′.0	0.1985	3	41.5			3.90	1.785	3.81×10⁻³	6.19	6.16	2.97	4.96
3	18°.20′.0	0.2496	3	65.3			5.32	2.793	5.96	7.79	6.83	3.39	5.63
4	28°.55′.0 / 29°.15′.0	0.4156 / 0.4.4	2 / 2	114.4			1.172×10^{-2}	6.154	1.313×10^{-2}	1.30×10^{-2} / 1.37	9.22 / 9.68	8.79	9.79
5	0.115	0.584	5	189.3			1.580	8.096	1.725	1.62	9.48	1.500	8.28
6	0.152	0.772	4 / 5	216.4 / 255.5	25000	30.250	2.096	1.095×10^{-1}	2.336	2.41	9.69	9.59 / 3.52	8.39
7	0.205	1.021	2	73.5			5.98	1.809	3.860	3.25	11.97	3.41	10.47
8	0.260	1.320	2	91.25			7.23	2.268	4.797	4.12	11.68	4.31	10.45
9	0.332	1.686	6	118.7			4.66	2.923	6.237	5.26	11.86	5.41	10.66
10	0.835	4.24	1 / 2	327 / 176	50000 / 50000	55.250 / 55.250	2.66×10^{-2} / 1.33×10^{-2}	8.048 / 7.620	1.627×10^{-1}	1.323×10^{-1} / 1.7[illegible]	12.93 / 12.44	12.70	11.50
11	0.525	4.21	1 / 2	50 / 320		5.250	2.44×10^{-2} / 2.61×10^{-2}	1.368×10^{-1} / 1.371×10^{-1}	2.276×10^{-1} / 2.925×10^{-1}	1.314	2.205		4.001
12	0.260	1.32	2	97			7.59	4.141×10^{-2}	8.236×10^{-2}	4.12×10^{-2}	2.14		
13													

* Standard Galv.

1 C.C. Phos. 0.4175 ℔ gives 73.6 divs. $= 5.98\times10^{-5}$ ℔ for 73.5 divs
$= 8.136\times10^{-4}$ ℔ " 1 div.

$2714 \times 1.727 = 4687 = 4.687\times10^{3}$ coeff of ξ

$\frac{1480}{59.63} = 24.81 \times 1.257 = 31.2$

Investigation of the economy of supplying the Pearl St. district N.Y. by a main feeder from Canal St.

Let w be the activity in all the lamps at full load (watts) near lamps

f - - - - the feeder " " "

h - - - - house wire mains - - - "

d - - - - dynamo armatures - - - "

m - - - - overcoming friction - - - -

β - - - fractional loss of activity of circuit lost in feeder at full load

n - - - fractional load at any time in lamps in terms of full load

r - - - average fractional load such that if continued steadily the annual losses and transmission would equal the actual the sum of the actual losses and transmission each to each.

y - - - number of seconds in a year.

c - - - cost of a watts per year. \$

$r_1\ r_2\ r_f\ r_d$ - - resistance of the lamps, mains, feeder, & armatures in equivalent lamp circuit

K - a constant of investment in feeder. copper.

φ - - function - - - - mon. + fitting.

Then $f = \beta\,(w + d + f + h) = \beta\,(W - m)$ Watts (1)

or $W = \beta\,(W - m) + m + w + d + h$ Watts (2)

or $W(1-\beta) = m\,(1-\beta) + d + h + w$ " (3)

and $W_n = mn + n^2\{\beta\,(W-m) + d + h\beta + nw$ " (4)

$J = W_n y = vy\,[m + w + v\{\beta\,(W-m) + d + h\beta\}]$ Joules. (5)

$Jc = cvy\,[m + w + v\{\beta\,(W-m) + d + h\beta\}]$ \$ (6)

Also $r_f = \beta\,(r_1 + r_f + r_2 + r_d)$

$$r_f(1-\beta) = \beta\,(r_1 + r_2 + r_d)$$

$$r_f = \frac{\beta}{1-\beta}\,(r_1 + r_2 + r_d)$$

$$c_f = \frac{K_f}{r_f} + \varphi(r_f)$$

$$= \frac{K_f(1-\beta)}{r_d\beta} + \varphi(\beta)$$

annual cost $q c_f = q\left\{\frac{K(1-\beta)}{\beta} + \varphi(\beta)\right\}$ \$

Total annual cost $C = cvy\,[m + w + v\{\beta\,(W-m) + d + h\beta\}] + q\left\{\frac{K(1-\beta)}{\beta} + \varphi(\beta)\right\}$.

$$\frac{dC}{d\beta} = cv^2y\,(W-m) + q\varphi'(\beta) - \frac{qK}{\beta^2}$$

$$\therefore \frac{qK}{\beta^2} = cv^2y\,(W-m) + q\varphi'(\beta)$$

Let $q\varphi'(\beta) = s$ since $\varphi(\beta)$ will generally be a linear function

$$\beta^2 = \frac{qK}{cv^2y\,(W-m) + s}$$

$$\beta = \sqrt{\frac{qK}{cv^2y\,(W-m) + s}}$$

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Kennelly Notebook #3

This notebook covers the period February-November 1890. It contains transcriptions by Arthur E. Kennelly of material from the rough record books used by experimenters in the Galvanometer Room. There are notes, drawings, tables, and calculations regarding a variety of electrical experiments, including tests of meters, batteries, induction coils, the magnetic permeability of iron, the carrying capacity of copper wire, and the production of copper by electrolysis. In addition, there are notes and design drawings of electric railway motors, including experiments conducted at the Edison General Electric works at Schenectady, and of low-horsepower motors for fans, dental equipment, and the phonograph. Also included are notes regarding 3-wire electric power systems, lighting plans for the Lick Observatory, tests comparing a Westinghouse and an experimental Edison transformer, and theoretical notes concerning physics, electricity, and mathematics. Among the experimenters whose work appears in this book are Jonas W. Aylsworth, Reginald Fessenden, and Alfred J. Thompson. At the end of the book is a subject index (filmed at the beginning of the book). The front cover is marked "III" and "1890." The book contains 160 numbered pages. Some pages were removed before the book was paginated. Graphs, blueprints, and other items have been pasted into the book.

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E5931-3

No. III.

Record Book

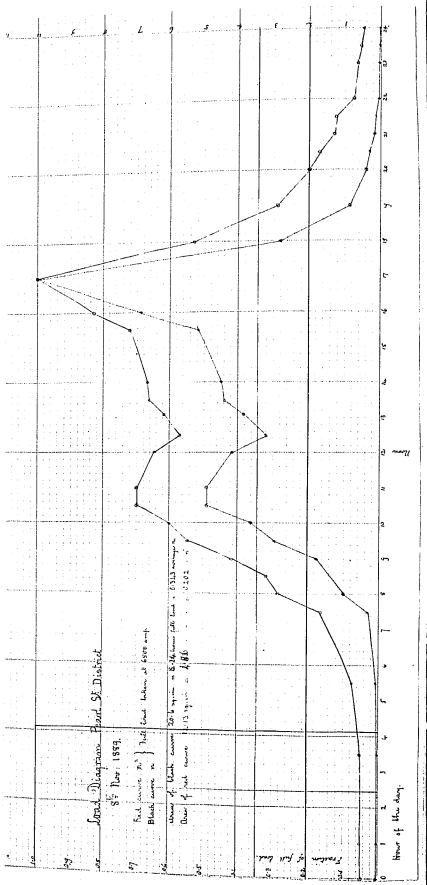
of

Observations, Measurements, Calculations and Data

compiled at the Edison Laboratory)

Orange N.J.

From 25th February 1890
to 3rd November 1890



On the economic transmission of power by single main feeders from Canal St to Fulton St New York, for the supply of 20,000 lamps.

First approximation. 25th Feby. 1890.

The distance being 4200 feet, on 3 wire system with the Edison composition lamp, the weight of copper at 15% drop will be about 244,000 lbs see preceding Record Book, p. 155. The cost of this annually at 20 ¢ per lb and 8% interest will be $3900.

The power to be delivered is $\frac{20000}{18}$ = 1110 HP. at full load and at 15% drop in feeders, the commercial efficiency of the system will be about 0.72 so that the H.P. lost in the feeders at full load = 1540 × 0.9 × 0.15 = 208. From the curve on the opposite page integrated by planimeter it appears that the average feeder loss is for this district 0.2 of the full load loss = 41.6 HP. At the estimated price of $50 per HP per annum this will represent $2080.

If the drop be made 20% the approximate yearly cost of copper (only) will be $2925, and the HP. lost will be approximately increased to $2800, making the loss 56 HP. on the average or 280 HP. at full load. The copper (only) in the feeder would be roughly $\frac{244,000}{4} \times 3$ = 183,000 lbs or $36,600

Test of a sample of specially prepared Rosin for Messrs Bergmann & Co. N.Y.

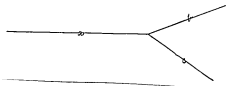
The sample differs distinctly from that previously furnished under the same, for test see preceding book. It is not nearly so non-inflammable being capable of supporting a flame when the substance is previously warmed. It is strong and takes a good thread also polishing well. Samples were set aside under seal.

Brief Account of Physiological Experiments made by H. P. Brown at the Edison Station in Columbus O.

March 8th 1890.

A calf had its hair clipped on the forehead and right side. Felt electrodes backed by copper plates and soaked in 5% NaHO solution were applied to these parts, and secured with cord. A current from the Siemens alternating Dynamo was applied at P.D. of 700 volts. 1600 revs per min = $\frac{8 \times 1600}{2 \times 60}$ = 106 ~ per sec. In falling to the ground the calf disengaged wire from forehead electrode thus not taking more than some two seconds of current. Calf struggled slightly but totally hint. Application renewed for 15 seconds or 15 seconds.

A horse was then treated similarly as regards electrodes. P.D. 750 volts 15 seconds application. Horse fell forward the instant the current was applied and gave no sign of life or movement on breaking circuit. Weight estimated at 900 lbs.



$$v^2 = \frac{2v\sqrt{a^2(\beta+\gamma)}}{a^2(\beta+\gamma) - b^2\beta - c^2\gamma} + \frac{\sqrt{a^2(\beta+\gamma)}}{\left[a^2(\beta+\gamma) - b^2\beta - c^2\gamma\right]^2} = \frac{-\sqrt{2a^2(\beta+\gamma)\left\{a^2(\beta+\gamma) - b^2\beta - c^2\gamma\right\}} + \sqrt{2a^2(\beta+\gamma)}}{a^2(\beta+\gamma) - b^2\beta - c^2\gamma}$$

$$v = \frac{\sqrt{a^2(\beta+\gamma)}}{a^2(\beta+\gamma) - b^2\beta - c^2\gamma} = \frac{\pm\sqrt{\sqrt{2}\,a^2(\beta+\gamma)(b^2\beta + c^2\gamma)}}{a^2(\beta+\gamma) - b^2\beta - c^2\gamma}$$

$$v = \sqrt{a}\left\{\frac{a(\beta+\gamma) \pm \sqrt{(\beta+\gamma)(b^2\beta + c^2\gamma)}}{a^2(\beta+\gamma) - b^2\beta - c^2\gamma}\right\}$$

This value of v will involve minimum weight of copper.

Particular cases.

When (1) $b = c$ $\quad b = \infty\gamma\beta$ $\quad v = \sqrt{\frac{a}{a+c}}$

(2) $\beta = \gamma$ $\quad v = \frac{\sqrt{a}\left\{2a + \sqrt{2(b^2+c^2)}\right\}}{2a^2(\beta+\gamma) - b^2 - c^2}$

(3) $a = b = c$ $\quad v = \frac{\sqrt{2}}{2}$

On the winding of a #4 standard Edison armature to give 50 volts mean alternating p.d. when driven in the field of a #4 machine at 300 revolutions per min.

The number of wires all round the O.S. #4 armature is 200. and the number of revolutions 1600 at 125 volts t.p.d.; The same machine as an alternator would give 79.55 volts t.p.d. and at 300 revolutions 14.9 volts at 5 ~. In order to increase to 50 the wires must be 670 = 335 turns.

The circumference available for winding on the armature after deducting for insulation tubes is 17.5" and if 1/2" turns be taken to each layer the diam: of covered wire = 0.031". With 0.015" for cotton leaves 0.076" #15 B.W.G. The depth of winding will be 0.364". This with 6 layers of paper @ 0.007" and two of rubber tape @ 0.010" gives 0.426" or finished diam: 7.142"

The winding will therefore be:—

One #15 BWG 0.072" four turns round (two deep + two wide) in each division, and 96 divisions on the armature = 384 turns in all (two double layers) = 768 wires round the armature.

At normal excitation the alternator will then give 57 volts at 300 revolutions or 304 volts at 1600 revs. per min the frequency being 5 ~ and 26.7 ~ respectively.

On the determination of the least weight of copper in a bifurcating feeder consistent with a given fall of potential from the source to each terminal at a given load.

Let a be the length of a given feeder in cms.
b and c . . . . of its bifurcations . .
σ_a σ_b and σ_c be the conductance of these respectively.
β & γ be the given load currents in b and c (amperes)
V the fall of potential in the whole feeder
v . . . . . a the single part.
K a constant such that w = wt of copper per cm in = $K\sigma$.

Then $V - v = \frac{b\beta}{\sigma_b} = \frac{c\gamma}{\sigma_c}$.

$$b = \frac{a(\beta+\gamma)}{\sigma_a}$$

also
$$w_a = K\sigma_a \qquad W_a = Ka\sigma_a$$
$$w_b = K\sigma_b \qquad W_b = Kb\sigma_b$$
$$w_c = K\sigma_c \qquad W_c = Kc\sigma_c$$

$$\therefore W = W_a + W_b + W_c$$
$$= K\left\{a^2\frac{(\beta+\gamma)}{v} + \frac{b^2\beta + c^2\gamma}{V-v}\right\}$$
$$\frac{dW}{dv} = \frac{-a^2(\beta+\gamma)}{v^2} + \frac{b^2\beta + c^2\gamma}{(V-v)^2}$$

For max: or min:

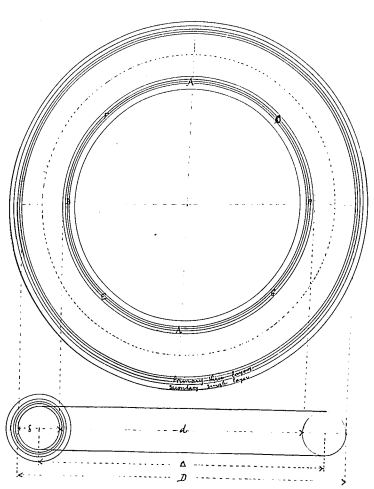
$$\frac{dW}{dv} = 0 \quad \therefore \quad a^2(\beta+\gamma)(V-v)^2 = v^2(b^2\beta + c^2\gamma)$$

$$v^2\left\{a^2(\beta+\gamma) - (b^2\beta + c^2\gamma)\right\} - 2vVa^2(\beta+\gamma) = -V^2a^2(\beta+\gamma)$$

$$v^2 - \frac{2vVa^2(\beta+\gamma)}{a^2(\beta+\gamma) - (b^2\beta + c^2\gamma)} = \frac{-V^2a^2(\beta+\gamma)}{a^2(\beta+\gamma) - (b^2\beta + c^2\gamma)}$$

Meteorological record.

Date.	Time.	Barometer Readings Inches	Barometer Readings Corrected.	Barometer Readings Temp.	Barometer Readings Corrected. Fahr.	Thermometer. Max.	Thermometer. Min.	Thermometer. Dry.	Thermometer. Wet.	Rainfall 24 hours.	Wind.	Remarks.
1890												
March 1st	Noon	29.674	75.39	75°	29.545	41.0°	38°	38°	—	.27	W.	Cloudy. Rain.
2	"	29.737	75.57	56°	29.672	40°	25°	27°	—		N.W.	Fair.
3		29.882	75.90	65°	29.793	31°	16°	25°	—	.06	W.	Snow.
4		29.894	76.08	71°	29.777	33°	17°	33°	—	—	S.E.	Fair.
5		29.934	76.05	73	29.811	30°	30	34°	—	—	W.	Fair.
6		29.800	75.70	64°	29.704	39°	21°	29°	—	snow	W.	Heavy snow.
7		30.070	76.43	60°	30.006	29°	6°	20°	—	—	W.	Fair.
8		30.100	76.46	66°	29.938	27°	13°	25°	—	—	N.W.	Fair.
9												
10		30.292	76.95	73°	30.169	45°	18°	43°	—	—	S.E.	Overcast
11		30.068	76.37	75°	29.939	44°	30°	40°	—	.32	E	Rainy.
12		29.968	76.12	81	29.821	64°	43°	68°	—	—	S.W.	Fair.
13		29.920	76.00	73°	29.777	67°	45°	64°	—	—	S.W.	Fair.
14		29.882	75.91	77°	29.747	67°	40°	47°	—	.61	W	Rainy.
15		29.652	75.32	74°	29.526	42°	31°	31°	—	.42	W.	Rain storm.
16		29.714	75.73	68°	29.506	41°	25°	32°	—	—		Fair
17		29.470	74.86	73°	29.347	41°	22°	37°	—	—	N.E	Fair
18	Noon	29.511	74.66	75°	29.382	47°	32°	46°	—	—	S.E	Fair
19	"	29.301	74.43	66°	29.173	52°	30°	37°	—	—	W	Heavy snow
20	"	29.997	75.04	77°	28.866	41	22	40°	—	—	S.W	.18 melted snow
21	"	29.385	74.66	76	29.253	47.	37.	48	—	—	S	Overcast.
22	"	29.495	74.94	75°	29.374	50	44	44	—	1.00	S.W.	Rain.
23	"	29.103	75.46	51°	29.446	46	38	40	—	.59	—	Rain
24	"	30.263	76.87	70°	30.149	41	25	35	—	—	S.W.	Fair
25	"	30.213	76.56	74°	30.087	42	31	41	—	—	S.E	Overcast
26	"	29.503	74.94	77	29.366	58	41	53	—	.18	W.	Fair.
27	"	29.763	75.60	76°	29.631	54°	37°	45°	—	—	S	Fair Overcast.
28		29.233	74.26	70	29.119	49°	33	38°	—	.9	S.W.	Rainy
29		29.511	74.99	68°	29.403	41	31	37	—	.04	W	Overcast
30		29.723	75.50	71°	29.604	43	30	41	—	—	W	Snow Overcast.
31		30.123	76.52	73	30.000	49	29	43	—	.05	E	Fair Overcast.
April 1		30.111	76.57	69°	30.000	51°	31°	40	—	—	N.W.	Fair.
2		30.281	76.94	74°	30.186	52.0	27°	41°	—	—	W.	Fair Overcast.
3		30.063	76.36	77°	29.922	62°	32°	52°	—	—	S.E	Fair
4		29.513	75.06	76°	29.481	63°	37°	52°	—	.35	S.E	Rainy
5		29.823	75.76	77°	29.688	59	40	46	—	.31	W	Fair Windy.
6												
7		29.499	74.93	79°	29.358	61°	31°	56°	—	.03	S.W.	Hazy, Overcast, Fair
8		29.777	75.64	81°	29.630	60°	36°	50°	—	.21	S.E	Overcast Rainy.
9		29.373	74.62	75°	29.248	56°	41°	48°	—	.57	S.W.	Rainy.
10		29.453	74.82	81°	29.305	58°	44°	51°	—	.13	S.W.	Fair.
11		29.827	75.77	77	29.771	56	32	43	—	—	W.	Fair.
12		30.043	76.32	80	29.898	66°	40°	57°	—	—	E	Fair
13		29.707	76.47	70	29.593	76	40	76	—	—		Fair
14		29.667	75.30	69	29.556	75	50	68	—	.035	S.W.	Fair
15		30.013	76.24	75°	29.878	70	43	62	—	—	W	Fair
16		30.153	76.60	80	30.009	68	36	61	—	—	S.W.	Fair.
17		29.817	75.76	66	29.785	67	42	59	—	—	S.W.	Fair Overcast
18		29.623	75.25	78°	29.486	63	43	52	—	—	W	Fair
19		29.945	76.07	69	29.830	69	29	45	—	—	N.W.	Fair
20		30.085	76.43	60°	30.001	63	35	54	—	—	S.W.	Fair
21		30.083	76.42	64°	29.981	67	42	59	—	—	W.	Fair
22		30.133	76.54	65°	30.034	16	43	63	—	—	W.	Fair Overcast
23		29.953	76.09	60°	29.869	68	38	66	—	—	E	Fair Overcast
24		29.813	75.81	66°	29.711	76°	56°	74°	—	—	S.E	Overcast
25		29.868	76.10	72°	29.749	76	44	64	—	.26	W	Rainy.
26		30.133	76.52	73°	30.010	49	33	45	—	.01	N.	Foggy
27		29.583	75.22	59°	29.502	48	48	40	—	.24		Rainy
28		29.859	75.93	62°	29.769	61	44	56	—	.01	N.W	Overcast Fair
29		29.803	75.71	64°	29.787	69	40	59	—	—	S.E	Overcast Fair
30		29.671	75.40	76°	29.539	61	45	57	—	—	S.E	Overcast Fair
May 1		29.525	74.00	68	29.444	82	53	75	—	.15	N	Overcast
2		29.943	76.07	68	29.857	18	39	53	—			Overcast



d at A.A. 19.80 at B.B 19.1 Mean 19.95

D - B.B 25.1 - A.A. 25.1 " 25.1

Δ " 22.03

δ - C 3.1 at E 3.1 at F 3.2 at G. 3.2 - 3.15

δ_1 3.65 δ_2 3.9 δ_3 4.3 δ_4 5.0

364 turns of s.c. covered copper wire 0.0145" (0.126) covered

6 0.056" (0.142) layer on first layer above oil paper.

358 turns of same wire on second layer above oil paper

352 - - - - third - - -

1074 - in all on primary circuit

280 - of same wire on one layer in secondary circ.

The induction through the external coil of n turns from a primary of 3 layers each having p_1 p_2 + p_3 ($p_1+p_2+p_3$) m turns is

$$4\pi n m \left[\frac{\pi \delta_1^2 + \pi \delta_2^2 (\mu-1) + \pi \delta_3^2 + \pi \delta_4^2 (\mu-1) + \pi \delta_5^2 + \pi \delta_6^2 (\mu-1)}{8} \right] + \left\{ \pi (\delta_1^2 - \delta_2^2) + (\delta_3^2 - \delta_4^2) + (\delta_5^2 - \delta_6^2) \right\} + \pi \delta_1^2 \mu$$

$$\pi \delta^2 m m \left[\delta_1^2 - \delta_2^2 + \delta_3^2 - 3\delta_4^2 \right]$$

$\therefore$

$$\frac{4N}{D} = \frac{4296}{22.03} = 195.0$$

Permeability of Iron Sample from Schenectady.

An anchor ring of iron containing 7 parts by weight of aluminium to 107 of ordinary cast iron or 6.54 % was cast at Schenectady in company with a series of other samples. The weight of the ring in air was 139 oz (3940 grs) and in water 118.5 oz (3360 grs) corresponding to a sp. gr. of 6.79. The dimensions of the ring are shown on the opposite page. The volume of the ring should be $\pi D \Delta \delta = 9.87 \times 2.203 \times 3.1 = 67.14$ cc. Three layers of primary wire were connected in series and brought to a reversing switch which was brought to the 118 volt dynamo thro galvanometers and resistances. The discharge through the ballistic galvanometer in the secondary circuit represents 560 times d single induction.

No. of Expt.	Condenser	Coll. & Imp.	q.	Throw.	Mean throw accepted	Value of 1 div		
	1 μ	1 1 2.442	1.4275 × 10⁻⁶	172 176.5 176.5 175.5 176.5 176 175.5 175 179 179 175.5	179	7.972 × 10⁻¹⁰ abs. qu.		
		1 2						
		1 3						

N.B. Cross

No. of Series	Clock Gauge	C.	(B-B)	No. of Obs.	Mean Throw	Aver. in cat.	Total cor. of cat.	Q/250	Q/Mass	Q/πD²Δδ	Q/π²N(ad)²	Σ(Δd²)/Nd²	μ	B
1	5.25'	0.0426 0.0426	16.64 16.44	4	127	–	5250	3.546 × 10⁻⁶	2.018 × 10⁻⁶	2.48 × 10⁻⁶ 2.45 × 10⁻⁶	27.7	0.58	26.49	25.55
2	6.15'	0.0836		5	146.2			6.578	3.453		12.56		26.92	43.37
3	9.0'	0.1194	23.29	90	64.2			9.102	4.80		18.15		25.87	60.26
4	13.45'	0.1765	35.98	5	96			1.523 × 10⁻⁷	7.996		28.04		27.94	100.5
5	17.30	0.2379	46.38	7	139			1.939 × 10⁻⁷	1.039 × 10⁻⁶		36.114		28.17	130.7
6	0.065	23.5'	0.3213 0.3230	63.6	5	198.6	–	2.827	1.484		49.55		29.37	186.8
7	0.215		1.092	2.13	3	245	25.000	3.256	1.710		166.4		62.62	1330
8	0.240		1.219	237.7	9	264	25.000	3.739	1.963		195.36		60.79	1446.5
9	0.245		1.246	242.6	4	143.1	50.000	2.017	1.025		189.1		58.87	1428
10	0.271		1.376	268.4	6	176.5	50.000	2.513	1.318		229.2		65.75	1765
11	0.312		1.584	308.9	5	222	50.000	3.161	1.746		285.6		71.93	2224
12	0.359		1.823	355.5	4	271.6	50.000	3.867	2.136		277.1		76.50	2720
13	0.359		1.823	355.5	4	136.9	100.000	1.949	2.051		277.1		73.44	2612
14	0.443		2.183	425.8	5	173	100.000	2.463	2.592		331.8		77.52	3301
15	0.525		2.666	521.9	4	207	100.000	2.947	3.102		405.2		75.98	3966
16	0.513		4.128	805.1	4	278	100.000	3.958	4.166		627.5		63.39	4388
17	1.35		6.852	1337	4	320.5	100.000	4.553	4.793		1012		46.09	4985
18	1.780		8.934	1753	3	195	200.000	2.776	3.592		1361		44.57	4788

$$\pi^2 m n d^2 = 9.8696 \times 280 \times 1074 \times 9.924 = 2.946 \times 10^7$$

where $4.0 \times 10^7 \times 2.8 \times 10^2 \times 1.1 \times 10^3 \times 1.42 \times 10^{-2}$

$$\pi^2 N d^2 = 9.8696 \times 1074 \times 9.924 = 1.052 \times 10^5$$

$$\frac{\pi^2 N}{Q} d^2 = \frac{1.052 \times 10^5}{6.92 \times 10^7} = 1.520 \times 10^3$$

$364 \times 3.65^2 = 4849$

$358 \times 3.9^2 = 5445$

$352 \times 4.3^2 = 6508$

$1074 \times 3.15^2 = 16,802$ } 1.576

area of ring = 7.792 sq. cm.

Calculation of the correction for winding spaces to be applied to a continuously wound Faraday ring before the true value of the permeability can be deduced.

Let d be the diameter of the cross circular section of iron (cms)
" d_1 " " " " " 1st layer of primary (mean) cms.
" d_2 " " " " " 2nd " " "
" d_r " " " " " rth " " "
" n_1 " " number of convolutions of 1st layer
" n_2 " " " " " 2nd "
" n_r " " " " " rth.
" m " " total " " " in secondary layer or layers assumed to be symmetrically disposed.
" $N = (n_1 + n_2 + \quad + n_r)$
" μ be the true mean permeability
" γ_0 " " strength of the magnetizing current (abs. mag) mean ring circumference

Then the induction φ through the secondary is expressed by the equation

$$\varphi = 4\pi m \gamma_0 \left\{ \frac{n_1\pi}{\sigma_1}(d_1^2 - d^2) + \frac{n_2\pi}{\sigma_2}(d_2^2 - d^2) + \frac{n_r\pi}{\sigma_r}(d_r^2 - d^2) + \quad + \frac{4N\pi^2}{\sigma_r}\mu d^2 \right\}$$

$$= 4\pi^2 m \gamma_0 \left\{ \frac{n_1}{\sigma_1}(d_1^2 - d^2) + \frac{n_2}{\sigma_2}(d_2^2 - d^2) + \frac{n_3}{\sigma_3}(d_3^2 - d^2) + \quad + \frac{N}{\sigma}\mu d^2 \right\}$$

$$\pi^2 m \gamma_0 \frac{N}{\sigma}\mu d^2 = \varphi - \pi^2 m \gamma_0 \left\{ \sum \frac{n_r}{\sigma}(d_r^2 - d^2) \right\}$$

$$\therefore \mu = \frac{\varphi}{\pi^2 m \gamma_0 \frac{N}{\sigma} d^2} - \frac{\left\{ \sum n_r (d_r^2 - d^2) \right\}}{N d^2}$$

$$= \frac{\varphi}{\pi^2 m \gamma_0 \frac{N}{\sigma} d^2} - \frac{\sum n_r d_r^2 - N d^2}{N d^2}$$

$$= \frac{\varphi}{\pi^2 m \gamma_0 \frac{N}{\sigma} d^2} + \left(1 - \frac{\sum n_r d_r^2}{N d^2}\right)$$

When the winding space is negligibly small $\sum n_r d_r^2 = N d^2$ and the correction vanishes.

For a hollow ring solenoid enclosing a vacuum the induction would be $4\pi m \frac{N}{\sigma} d^2 \frac{\pi}{4} \gamma_0 = \pi^2 m \frac{N}{\sigma} \gamma_0 d^2$ and μ reduces to 1 so the above equation checking its accuracy

H is always $= \frac{4\pi N \gamma_0}{\pi D} = \frac{4 \cdot N \gamma_0}{D}$ where D is the mean diameter of the ring along the lines of force. $= 4 \frac{N}{\sigma} \gamma_0$

Error of Barometer Scale in Galvanometer Room (Office observed 16th Mar. 90 by cathetometer

Altitude of 27" mark.	88·052	upper telescope	88·052	
" " lower side of 100" mark on scale of thermometer	62·011		62·011	
	26·041		26·041	26·044
Altitude of 100" mark as above	57·396	lower "	57·396	
" " base point	14·803		14·803	
	42·493		42·493	42·493
" 27" mark above base point	68·535			68·537

At a distance of 90 cms 1 div: of level bubble represents 0·01 cm Mean 68·536.

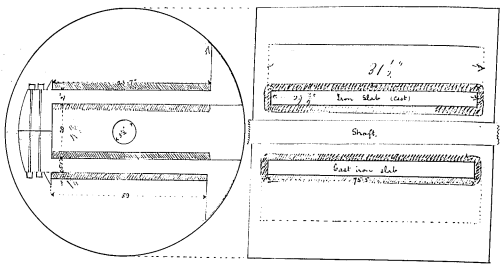
27"·000 indicated	68·580 cms indicated	
26·983 observed	68·536 " observed	
·017" over indication	0·044 " over indicated	

So that 0·017" or 0·044 cms have to be subtracted from reading.

Scale 1/10

Section of interior of drum at right angles to axis.

Section of interior of drum through axis.



240 lbs of ⅜ in B.W.G. on each slab or 480 lbs in all.

On the winding of an ore-milling magnet to be operated within a revolving brass drum.

The free surface of this magnet will be 85 × 60 × 2 = 10200 sq. cms. and allowing 20 sq. cms. per Watt gives 510 Watts available. = 100 volts @ 5·1 amperes. The res: must therefore be $\frac{100}{5.1}$ = 19·61 ω (that) say 19·6 ω or

The diameter of the wire intended to be used is 0·109" (12 B.W.G.) ground to 0·128" and 23/128 = 180 turns in one layer and each turn will be about 5·5' so that 1 layer will have 990 feet = 1·13 ω.

15·6 ω @ 163·39 lbs per ω = 600 lbs = 3140 lbs ω 7·84 ω on each slab = 7 layers on each slab.

The total number of feet will be 7 × 180 × 5·5 = 6930 on each half (1260 turns) and 2520 turns or 13860' feet on the magnet.

2520 × 5·1 = 12850 ampere-turns.

Measurement made to secure the accuracy of two standard resistances of copper wire, one for Messrs Bergmann & Co., and one for ourselves, each to be 46·46 ω of copper @ 70°F (21·1°C) and to be of # 29 B.W.G.

Preliminary measurement. 300 cms. of this wire 0·0124" diam: counts to 0·015" = 0·677 ω @ about 20°C. = 2.257×10^{-3} ω per cm.

The wire for 50 ω as 1st approximation will have to be wound on an arbor 17·35 cms: in diam = 54·5 cms: in circumference.

$50/2.257 \times 10^{-3} = 22.15 \times 10^{3} = 2.215 \times 10^{4}$ cms: of wire

$2.215 \times 10^{4}/5.45 \times 10^{1} = 406.4$

Measurements made of the energy required to be delivered by a battery for electro cauterizing purposes.

As contained from Dr. Edward Yatman of Yonkers N.Y. that the diam: of platinum wire used in electro cautery is generally 0·0253", and that "while 2" is frequently sufficient "the length used does not probably exceed 4" in any of the burners ordinarily employed". Very rarely 6 or 8" of # 18 wire 0·0140" have been used.

Experimented with Pt. wire 0·016".

15·25 cms: of this wire was brought to bright redness by a current of $\frac{1.62}{0.19}$ = 7·02 amperes when the p.d. on the wire was 4·5 volts.

4" = 10·2 cms. + $\frac{10.2 \times 4.5}{15.25}$ = 3·0 volts.

Next tried 4 wires each 0·012" diam. the strand being 0·025" in diam. This was brought to vivid redness by $\frac{2.60}{.197}$ = 13·2 amps. and the p.d. on 15·25 cms. was 3·5 volts. on 10·2 cm it would be 2·33 volts.

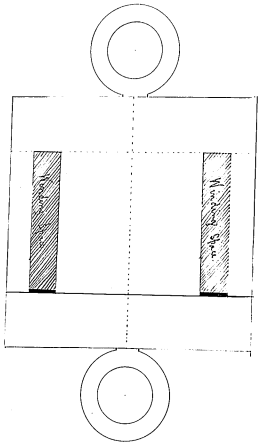
For the 0·016" wire, assuming each K.H.O. cell to have 0·7 volt and 0·03 ω int: res:

$3.0 = 0.7n - 7 \times 0.03n \quad \therefore n(0.7 - 0.21) = 3.0 \quad n = 6$

For the 0·025" wire assuming the same values

$2.33 = 0.7n - 13.2 \times 0.03n \quad \therefore n(0.7 - 0.396) = 3 \quad n = 10$

allowing negligible resistance in the leads.



Cross section in diametrical plane.
Full size.
Annealed wrought iron.

On the Dimensions of an Electromagnet capable of sustaining 200 lbs weight.

The formula for lifting power is

$$Wg = 2\pi I^2 + HI$$

Where W = mass lifted per sq. cm. cross section
g = acceleration of gravity
I = moment per c.c.
H = field.

$$I = \kappa H$$

and $\mu = 1 + 4\pi\kappa$

$$\therefore \quad I = \frac{H(\mu - 1)}{4\pi}$$

and

$$Wg = \frac{H^2(\mu - 1)^2}{8\pi} \qquad \ldots\ldots (1)$$

Where μ is a large number this reduces to

$$Wg = \frac{H^2\mu^2}{8\pi}$$

$$= \frac{B^2}{8\pi}$$

By employing wrought iron with $H = 40$ $\mu = 1000$ say

$$Wg = \frac{100{,}000{,}000}{25}$$

$$= 4{,}000{,}000$$

W = 4000 gms. per sq. cm.

200 lbs = 90600 = 22.75 sq. cm. cross section.

With a circular core = 5.4 cms in diam. = 2.2".

For H to be 50 as factor of efficiency of 4
there must be 40 ampere-turns per linear cm.

With a clearance of 1 cm. on a side we have

$$0.7854(x^2 - 7.4^2) = 22.75$$

$$x^2 = 54.76 + 28.97$$

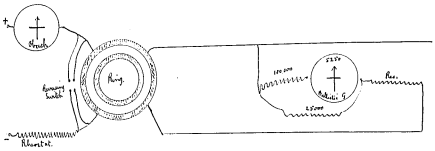
$$= 83.73$$

$$x = 9.15$$

The mass of the magnet thus formed, and represented in section on the opposite page will be:–

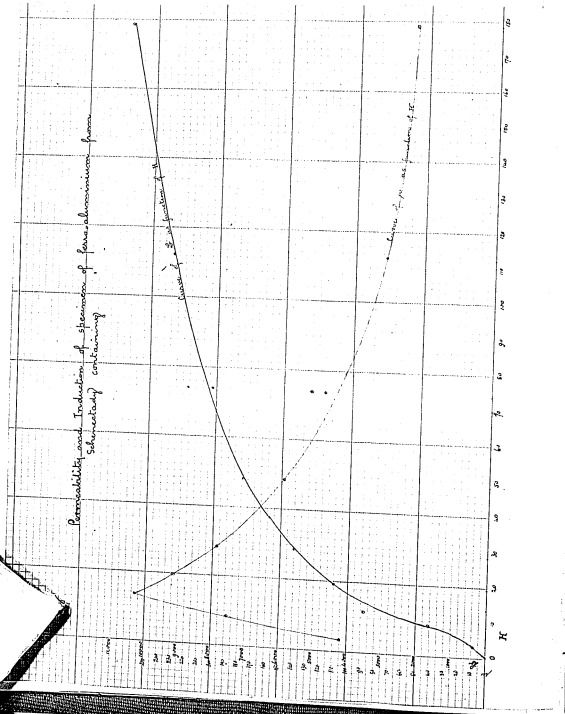
approximately $\dfrac{9.15 \times 0.7854 \times 9.15^2 \times 7.7}{453.6}$ lbs

$= 10.2$ lbs.



$$\phi = \frac{7\,d \times 5.91 \times 10^{-10} \times 5.21 \times 10^{8}}{2 \times 364} = 4.23 \times 10^{-3}\ \text{rd}$$

$$H = \frac{990 \times 1.257 \times C}{2g \cdot 2} = 17.98\ C$$



Permeability of sample of iron from Schemectady. contd from page 14.

The ring whose test on page 14 was found to be in error was again used. The inner layer of 360 turns was used as the demagnetising coil, and the outer (two layers connecting) 990 turns were used as primary. The following observations were then obtained:—

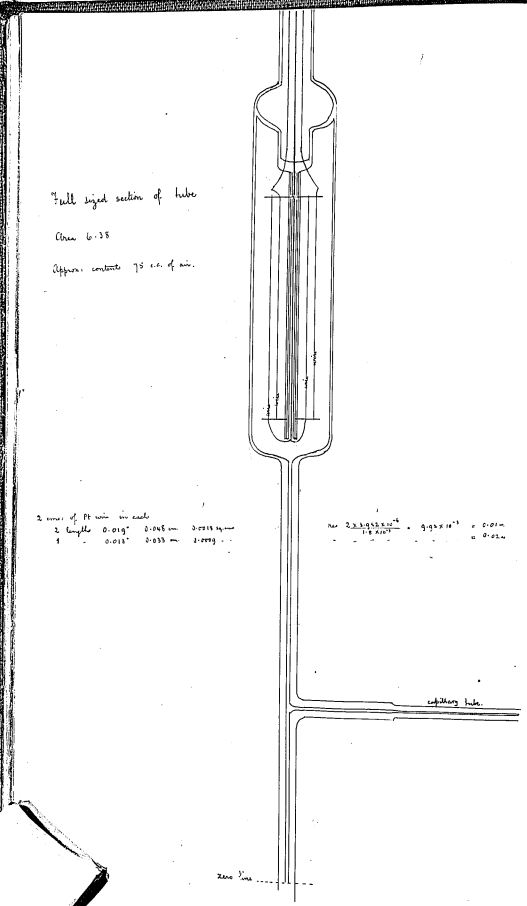
No.	Bell + Leads	a	Throw on Ballistic G.	v	$\frac{0.1453 Zv}{m\sqrt{n-1}}$	Result	Value of 1 div. in q.
1	1.4275 + 1	1.4275×10^{-7}	240	−1.6			
2			236	+2.4	0.0332 × 10.9		
3			239	−0.6	0.363	238.4 ± 0.4	$\frac{1.4275 \times 10^{-7}}{2.4415 \times 10^{4}}$
4			236.5	+1.9			
5			238	+0.4			
6			241	−2.6		Point of reversal 40 secs.	
7			239	−0.6			
8			238	+0.4			
9			238	+0.4			= 5.91 × 10⁻¹⁰
			7149	+ 0			
			238.4	± 10.9			

No. of Obs.	Time	Standard Galvo.	Steady	Current amp.	H 4.23 T	No. of Obs.	Mean Throw	Res. of Galvo.	Res. in manganin	Total res. in circuit	q	B	μ	H
1	9.20	41°50′		2.199	8.26×10^{-6}	6	314.3	20 200	–	20,200	2932	376 9.2%	105	3.58
2	.40	31°45′	0.096	0.467 / 0.457		4	150.4		–	–	12,960	1650 33%	188.4	8.57
3	.55		0.150	0.762		7	321.7				27,500	35303.2%	257.5	13.71
4	10.03		0.210	1.066	1.92×10^{-5}	5	179.4	–	25000	45200	34,200	4460 0.37%	129.5	19.77
5	10.19		0.310	1.574		7	227.8	–	–	–	43560	5590 0.6%	197.0	28.31
6	10.25		0.527	2.676		5	290.6	–	–	–	55570	7130 0.7%	148.2	48.13
7	.47		0.81	4.112		1	360	–	–	–	68,820	8830 0.9%	119.4	73.96
8	.45		0.81	4.112	2.97×10^{-5}	2	213	–	50000	70200	63,260	5120 0.7%	109.8	73.96
9	10.53		1.295	6.268		3	245	–	–	–	72,770	9140	82.9	112.7
10	.57		1.955	9.924		4	280	–	–	–	93,180	10780	59.9	178.5

$D = 0.1025 + 0.000059\,H$

Bell + leads	a	Throw on Ballistic G.	v	μv	$\frac{0.1453 Zv}{m\sqrt{n-1}}$	Result
1.4275 + 1	1.4275×10^{-7}	242.5 (1)	2.05	4.1	0.1 × 13.35	244.55 ± 0.4
		249 (1)	4.65	4.65	= 1.335 error of single obs.	
		243 (1)	1.55	2.10	+ $\frac{1.335}{\sqrt{11}}$ = 0.4	
		245 (1)	0.45	1.35		
		245 (1)	0.45	1.35		244.55
		$\frac{50}{11}$ = 4.55		13.35		238.4
		244.55				482.95
						241.475 Mean of both results.

Multiplying power of Shunt 5.21



Experiments upon the temperature coefficient of resistance of copper.

(9)

Kennelly and Fessenden.

Three attempts had been previously made to determine the rate and change rate of this coefficient by means of a coil of copper wire in a glass chamber filled with air employing the principles of the air thermometer, but in each case the result proved abortive from mechanical deficiencies. Apparatus #1 was a larger glass tube heated by an oil bath itself heated by bunsen burner. This bulb leaked and the general method was unsatisfactory. #2 was a similar tube drawn to scale on page 142 Book II. This bulb burst for want of strength when subjected to the stress of heat pressure. #3 was a smaller tube on an improved plan but when completed the coil of wire within was found to be broken. The following however is a description of #4, which was more successful.

A glass tube about 0.25 in diam. ext. and 18 long formed a shaft in the axis of a larger tube blown into a bulb. This outside bulb was of the dimensions shown on the opposite page. At nearly equal intervals along the central tube shaft and at planes at right angles thereto were fixed disks of mica each 1.9 in diameter. These were kept in place by washers of glass tubing fitting closely upon the inner shaft. All these disks were bored with 15 holes in two concentric rings, and through these holes one fine wire was longitudinally threaded ~~backwards~~ up and down in direct succession, the inner circle being completed before the outer circle was ~~complete~~ completed. About 120 cms. of the wire was thus threaded in each circle, the diam. of the inside circle being about 1.0 and that of the outside 1.6. The resistance of each circle was about 10 ω at normal temperature. Wires to the ends and junction of these circles were led through platinum seals outside the tube, in the manner of incandescent lamp connections.

The wire was of copper 0.0051 in diam (0.002"). It was originally silk covered, but the covering was removed by immersion in strong KHO solution.

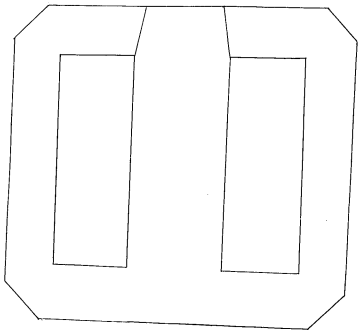
The bulb terminated below in a narrow tube of glass 0.4 in diam. ext. and 0.6 ext. and about 15.2 long to the zero line. At right angles to this tube there projects another at right angles as shown. By observation on a separate tube it has been determined that the approximate capacity of this length of tube in both directions is 0.2 c.c.

Surrounding the bulb is a frame wound with 16 ω of platinoid wire, and outside this conical frame is a shell of asbestos. The whole bulb & frame are then contained in a percolator through whose orifice the lower end tube passes water tight by a rubber stopper. The percolator was then filled with boiled linseed oil, and a disk of asbestos laid on above as a cover. About 3 amperes was passed through the platinoid wire and served to raise the temperature of the oil bath.

A bottle of mercury was suspended from the ceiling by a cord over two pulleys and a counterpoise sand-bottle. The mercury bottle communicated by rubber tubing with both the lower glass tube of the bulb and a long vertical index tube. At starting, the temperature and pressure of the air in the bulb was determined and the capillary offset tube then sealed by blowpipe while the mercury stood at the fiducial mark. The heating current was then passed through the platinoid coil as soon as the resistances of the enclosed coil had been determined. The heated enclosed air as it drove the mercury downwards was forced back to zero by raising the mercury bottle and reading off the increase of level by cathetometer on and off the index tube. The bulb had been repeatedly exhausted before commencing and refilled with dried air.

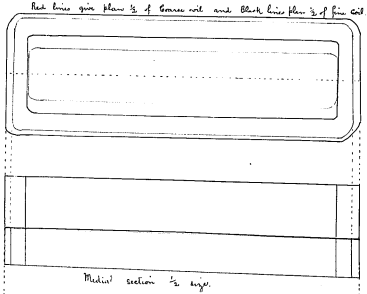
Experiments on the Temp: Coeff: of copper continued.

No. of Obs.	Calorimeter Reading	Calorimeter Rise:	Resistance with heat distributed a	coil b	a & b	Time 16. II. 90	Temp: of Hg:						
1	11.326	zero	9.922	9.839	20.267	20.1265							



Plan of one plate in transformer
actual size.

Red lines give plan ½ of Primary coil and Black lines plan ½ of fine coil



Medial section ½ size.

Tests of a Westinghouse Converter.

Weight of converter without shell

Primary coil	1520
Secondary	1560
Iron plates	9580
Bolts & frame	1170
	13830

Each plate has a thickness of 0·007" to 0·008" and the paper 0·003" to 0·004".
The coils have the dimensions shown

Resistance of primary coil 22·28 ω.
" " secondary " 0·05 ω.

In primary coil 16 layers of 45 turns each = 720 turns.
" secondary " 5 " 7 " " = 35 "

Diam: of primary wire 0·025"
" " secondary " 0·127"

As it was difficult to ascertain the permeability of the magnetic circuit accurately owing to the want of symmetry in the arrangement a fixed current was passed through the primary coil, and the effect of its reversal noted on the ballistic galvanometer placed in the secondary circuit. The plates were then all removed and iron wire 0·0265" wound on in to plates by hand through and through. The weight of wire added was 21100 gms: or 0·22 of the weight of plates. The experiment was then repeated with following results.

With plate magnetic ct.							With wire magnetic ct:							
Deflection of galvo.	Current	Rev. of Ballistic ct.	Turns	value of 1 div. sec.	φ		Deflection of galvo.	Current	Rev. of Ballistic ct.	Turns	value of 1 div	φ	φ approx.	
27·30	0·393	205,250	197	7·97200	4·605×10⁵		27·30	0·393	205,250	62	7·85500	2·31305 × 62 = 1·434×10⁵		

If the weight of wire were increased to that of the plates we might expect a corresponding increase in induction i.e. to 6·518 × 10⁵ an increase of 41·5% over the induction with plates.

22·28 × 0·[illegible] = 2·551 Volts.
[illegible] × [illegible] = [illegible] × [illegible] = [illegible]
22·28 × [illegible] × [illegible] = [illegible]

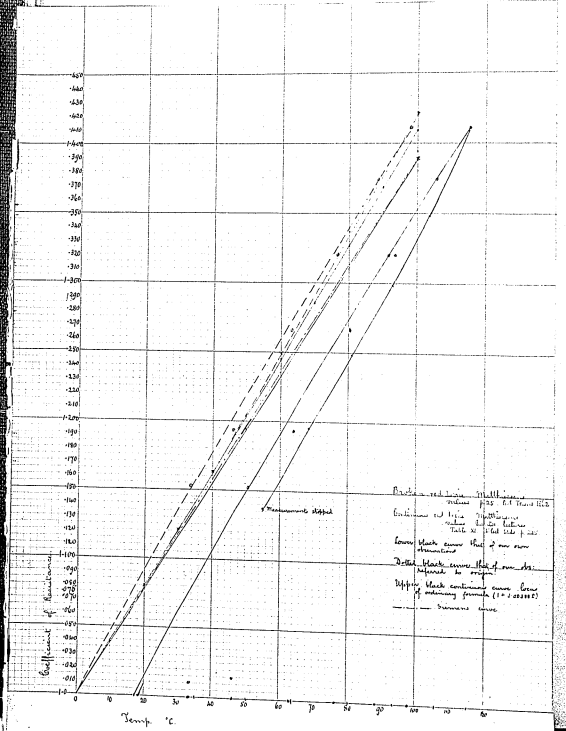
The inductance is 600,000 lines (φ) for one ampère × 730 = 438,000,000 = 0·438 quadrant. for the primary. The inductance mutually excited on the secondary will be 600,000 × 35 = 21,000,000 = 0·021 quadrant and the inductance of the secondary on itself will be presumably 1,018,500 = 0·001 quadrant.

Res. of leads in the apparatus itself = 2 cms. of platinum 0.010 in each wire
+ 0.014 0 0.021 − 0.014

Res. of leads proper a + b 0.328 + 0.037 = 0.365
b + c 0.326 + 0.037 = 0.363
a + c 0.343 + 0.025 = 0.371

Observed height of barometer when sealing off bulb 74.82
Index error +0.46
74.776
Correction for temp. −.267 (67.8)
74.509

Temp. of oil bath by Std. Thermometer 17.2° C.

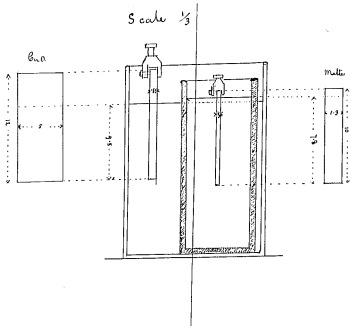


Time	Temp. of Bath	Approx. temp. of bath	Temp. of Bridge	Observed res. with leads	Corrected for leads 0.365	Observed res. for a	Corrected for leads 0.363	Observed res. for b	Corrected for leads 0.371	Galvanometer reading	Height of barometer	Temp. of Bath by calibrated th.	Observed temp. of Bath
20.0	15.4°C.	17.2°C.	20.5°C.	10.250	9.885	10.265	9.902	20.170	19.799	11.925	0	1.00279	15.4
.12				10.990	10.625	11.150	10.787		19.797	16.638	4.712	1.00283	15.6
.30				1		11.620	11.257	23.160	22.809	20.594	8.868	1.00287	15.8
.40				12.280	11.915	12.280	11.917	23.980	23.609	23.946	12.020	1.00290	16.0
.58			21.5°C.	12.960	12.595	12.970	12.607	25.440	25.069	28.270	16.344	1.00294	16.2
21.13				13.49	13.125	13.485	13.122	26.500	26.129	31.650	19.734	1.00297	16.4
.25		100°–105°		14.03	13.665	14.00	13.637	27.550	27.179	34.806	22.880	1.00301	16.6
.38	16.8°	102°–103°		14.36	13.995	14.30	13.937	28.300	27.929	37.158	25.232	1.00305	16.8
.55								27.050	26.679	36.260	22.332	1.00305	16.9
.00								26.070	25.699	31.435	19.510	1.00303	16.7
.06								25.070	24.699	28.320	16.394	1.00303	16.7
.16								24.02	23.649	25.190	12.264	1.00301	16.6
.29	16.6°		22.2°	11.620	11.255	11.600	11.237	22.97	22.599	21.790	9.864	1.00301	16.6
									295.828	345.984	192.946 152.938 345.884		

	Place of Bridge wire cell 6.05	Total No. of cells (+70/300)	Coeff.	Abs. temp. of wire at beginning	Abs. temp. of wire at time	Temp. by wire thermo. °C.	Resis. °C.	Resis. of res. Ω	Coeff. of res.	Coeff. per °C. wire	res. of 0°C	Curve of calibrate	Difference (Calc.) which
	–	70.510		17.2°C.							19.799	19.787	0.012
2	4.700	79.210	1.0631	= 290.2	308.5	35.5	18.3						
3	8.640	83.156	1.1160		323.7	50.7	33.5	3.010	1.1521	0.004537	22.809		
4	11.990	86.500	1.1609		336.9	63.9	46.7	3.810	1.1928	0.004129	23.609	23.832	* −0.223
5	16.295	90.805	1.2187		353.6	80.6	63.4	5.270	1.2662	0.004199	25.069	25.202	−0.133
6	19.670	94.180	1.2640		366.8	93.8	76.6	6.320	1.220	0.004178	26.129	26.247	−0.118
7	22.810	97.320	1.3061		379.0	106.0	88.8	7.380	1.373	0.004201	27.179	27.302	−0.123
8	25.160	99.670	1.3377		388.2	115.2	98.0	8.120	1.411	0.004194	27.929	27.932	−0.003
9	22.270	96.780	1.2989		376.9	103.9	86.7	6.880	1.3148	0.004214			
10	19.450	93.960	1.2610		365.9	92.9	75.7	5.900	1.2982	0.003964			
11	16.350	90.860	1.2194		353.9	80.9	63.7	4.900	1.2479	0.003891			
12	13.228	87.738	1.1775		341.7	68.7	51.5	3.850	1.1950	0.003797			
13	9.836	84.346	1.1320		328.5	55.5	38.3	2.800	1.1142	0.003708	22.599	22.492	0.107
								56.260 237.588 293.848					

On breaking the dynamo circuit through the heating coil in the oil bath, a fall in the resistance of the enclosed wire could be detected within two or three seconds and a fall of pressure by calthermometer in some ten seconds, thus proving that no time lag exists in the apparatus.

* The difference 0.012 at the head of this column is due to some slight want of symmetry or separation of the two interior coils. The greater differences later on are no doubt due to changes occurring in the time necessary to secure the three measurements as they are — for rising and + for falling temperatures.



Electrolysis of Copper Matte. 19th Mar. 30.

A glass battery jar contained a porous cell and both were filled with an aqueous solution of $NaCl$ of density 1·16. In the porous cell, a plate of matte was immersed 10 × 1·9 × 0·45 and exposing 38 sq. cms. to the liquid. In the outer jar was suspended a plate of phonographic cell compressed CuO. 12 × 5 × 0·85 exposing 180 sq. cms. The CuO plate weighed 227·6 grammes and the matte plate 57·8. The resistance of the whole cell was at first very high but by keeping the current from the dynamo through two lamps (1·1 amp) for 30 mins. the resistance of the cell at the end of that time was 1·8 ω. The following series of readings were then taken.

No. of Obs.	Lamps in cct.	Shunt reading	Current amperes	Density amp. per sq. matte	Density amp. per sq. foot	P.D. in cell volt	Res. of cell by bridge	P.D. due to res. volts	Counter emf volts	
1	1	0·098	0·49	129	12·18	3·0	1·8 ohm	0·9	2·1	
2	2	0·225	1·125	296	27·88	4·3		2·03	2·27	
3	3	0·340	1·70	448	42·1	5·4		3·06	2·34	
4	4	0·450	2·25	592	55·7	6·4		4·05	2·35	
5	5	0·550	2·75	724	68·1	6·9		4·95	1·95 ?	
6	6	0·650	3·25	856	80·5	7·6		5·85	1·75	
7	7	0·730	3·65	961	90·3	8·2		6·57	1·63	doubtful
8	8	0·840	4·2	1105	104	9·1	~~1·27~~ ?	7·56	1·54	
9	9	0·930	4·65	1224	115	9·5	~~1·32~~	8·37	1·13	
10	10	1·050	5·25	1380	130	10.	~~1·38~~	9·45	0·55 ?	
11	2	0·225	1·125	296	27·8	3·3	1·25 ohm	1·41	1·9	

Very little polarisation is visible in testing the cell but there is a nearly steady initial counter e.m.f. of nearly 2 volts. Testing current put on at 11.20 until 12.10 and from 13.40 to 17.30 when the matte was scraped. The resistance of the cell after scraping was about 1 ω (rather less 0·98), and the current 1·18 amp. the p.d. 2·3 volt. The scraping of the matte reduced the p.d. by 1 volt as it had been 3·3 volt for a long period previously. The counter e.m.f. after scraping would thus be as low as 1·2 volts.

The current was stopped at 20.50 when the p.d. was and the current 1·18 amp.

The weight of the matte plate after scraping and drying was 45·915 gm. The total loss was 11·9 grammes.

The current was 1·1 amp. from 11.30 to 12.10 = 0·67 hr @ 1·1 amp = 0·737
" " " 1·13 " " 13.40 . 18·0 = 4·33 = 0·113 4·90
" " " 1·18 " " 18·0 . 20.50 = 2·83 @ 1·18 3·33
8·97

8·97 amp. hrs. dissolved 45·915 grammes of matte.
1 " " " 5·12 " " " = 0·0113 lbs.
or 88·6 amp. hrs. will be needed for 1 lb. of matte. = 0·00393
342·2
2000 × 88·6 or 177200 . . . . . 1 ton .
646,000
Taking the e.m.f. of disruption at 2 volts (mean), each amp. does 2 foot lbs. of work in one second or 7200 foot lbs in one hour.
4 hr. 1000 1525200
177,200 × 2 = 354,400 watt hours = 12.62 H.P. hours electrical.
2000
@ 90% = 8154 mechanical H.P. hours

for electrolytic-force work alone independent of work against resistance

With H.P. for $50 per annum of 24 × 360 = 8640 hours, the cost of 1 H.P. hr = 50/8640 = 0·579 d so that 1 ton of matte will cost $2.97 for work expended in disruption.
21·81

If it were possible to keep the surface of the matte quite clear of debris, then the p.d. would be reduced in ratio 1·2/3·0 or 40% and the price per ton would become $1·50.

Electrolysis of Matte contd.

The experiment recorded on the last preceding page was repeated under two variations. (1) Using a carbon plate instead of a CuO plate (2) Using a solution of KNO_3 in H_2O instead of NaOH

Two battery jars with porous pots of practically the same dimensions as those shown on the preceding page were made up. No. 1. had a plate of matte 10 x 2 x {0.7 (matte)} immersed to a depth of 9.3 also a plate of CuO. 12.2 x 5 x 0.85 immersed to a depth of 9. The matte exposed superficially about 22 sq. cms. and the CuO about 65. The solution was KNO_3 in water the sp. g. being 1.26 in the outer and 1.20 in the porous cell. at 21.5°C. The weight of the matte plate was 57.61 The resistance of the cell was at first very high but reduced to 1.95 ω after about 20 mins. passage of 1 ampere.

No 2 cell had a matte plate 10 x 2 x {0.7 (matte)} immersed to a depth of 8, and a carbon plate 11.5 x 5.7 x 1.25 immersed to a depth of 10. The matte plate thus exposed about 25 and the carbon plate about 76 sq. cms to the liquid, which was an aqueous solution of NaOH sp. g. 1.156 at 21°C. The weight of the matte plate was 61.92. The resistance of this cell at starting was 0.7 ω. The dynamo current was sent through these cells in series and the clock at 11.22. the matte plates being the anodes. The current commenced at 0.88 amp: at 16.00 the matte plates were scraped. The debris on the KNO_3 plate was hard and stiff, that on the NaOH plate soft and yielding. At 19.55 the plates were scraped again. The observations during the run are shown in the table.

No. of Obs.	Time	Clock	Current	Amp. hrs.	Obs. P.D. (1) volts	Obs. P.D. (2) volts	Clock rec. (1) ω	Clock rec. (2) ω	P.D. from b rec. (1) volts	P.D. from b rec. (2) volts	Counter e.m.f. (1) volts	Counter e.m.f. (2) volts	Matte Equivalent density (1) amp. hr.	Matte Equivalent density (2) amp. hr.	Matte Equivalent density (1) amp. hr.	Matte Equivalent density (2) amp. hr.			
1	11.22	0.175	0.88	-			-	-											
2	.30	0.198	1.00	0.12	7.0	2.0	·	0.7		1.4		0.6							
3	.50	0.20	1.0	0.33	7.0	2.0	2.0	0.7	3.0	1.4	4.0?	0.6							
4	15.00	0.20	1.0	3.16	9.0	3.5	1.5	0.74	1.5	0.7	7.5?	2.8	4.55	4.00	42	37	Stopped to replace		
5	16.00	0.2	1.0	4.16	10.0	3.6													
6	16.40	0.215	1.08	4.91	3.2	2.3	1.5	0.7	1.6	0.7	1.6	1.6					Started		
7	16.30	0.215	1.08	0.96													Stopped for replacement		
8	16.40	0.23	1.16	0.00													Started		
9	19.55	0.212	1.07	3.66	10.5	3.6	4.9	1.3	5.2	1.4	0.2?	2.2					Stopped to change		
10	20.40	0.23	1.16	0.00	2.7	2.5	1.2	0.95	1.39	1.1	1.3	1.1					Started		
11	20.53	0.22	1.11	0.83													Stopped		
				9.44															

After swapping, drying and weighing the matte plates were

No. (1) 34.210 gms. equivalent to a loss of 17.41 g.
(2) 28.275 " " " " 13.665

No. 1. losing 17.41 g. in 9.44 amp: hrs dissolves 1.8443 gms. per amp. hr. &
" 2 " 13.665 " 9.44 " " " 1.4477 " " " "

96 1 lbs 1 lb in 2146 hrs 1 ton of 2000 lbs in 4.92000 kmp. hrs
" 2 " 1 " 313.5 " " " " 627000 " "

The mean counter e.m.f. in the no 1. cell was about 3.0 volts
" " " " " " 2 " " 2.0 "

The energy expended per ton in £1 is 14.76 Kwt. hrs for counter e.m.f.
" " " " " £2 " 15.24 " " " " "

1 Hp. hr. cost @ £50 per annum 0.5780 d
1 Kwt. — " " " " 2.776 = £11.65 for £1 per ton (a 98% cl. £12.72
= £ 9.73 " £2 " " £ 10.51

Electrolysis of Matte contd.

Took 6 battery jars in all important respects similar to the ones already described, with a solution of NaCl in H_2O of density 1.114 at 20°C. The porous cells contained matte plates 10 × 2 × 0.75, immersed for about 8 mm. In the outer jars were plates of carbon in three and plates of copper oxide in three 12 × 5 × 0.85.

The matte plates were weighed before and after the experiment, and two Edison standard meters were included in the circuit.

The experiment lasted more than 24 hour. The density of the solution at the end of that time was 1.165 in the porous cells, and 1.145 in the outer cells. The debris was loose and muddy, easily detached and weighed in all grammes or grammes per cell.

Cells 1, 2, 3 had CuO plates. Cells 4, 5, 6 had Carbon plates

No. of obs.	Time	Clock	Current	Amp. hr. in interval	Amp. hr. to time	P.D. on cells	Res. det.	P.D. due to res.	Corrected EMF of cells.	Remarks.
1	16.25	0.2	1.00	–	–	(1) 6.5 (2) 15.0 (3) 4.1 (4) 1.6 (5) 2.35 (6) 2.6				Started
(2)	17.55	0.198	1.0	1.5	1.5	(1) 3.5 (2) 6.2 (3) 2.0 (4) 1.75 (5) 2.69 (6) 3.65	1.3 1.95 0.9 1.25 1.05 1.0	1.3 1.95 0.9 1.25 1.05 1.0	2.2 2.2 2.1 2.0 2.6 2.6	
3 4	20.37 (8.10) 20.05 (8.10)	0.195 0.205	0.98 1.03	3.66 –	5.16 5.16	(1) 2.5 (2) 3.05 (3) 1.9 (4) 2.35 (5) 2.75 (6) 2.7	1.05 1.20 0.75 1.25 1.15 0.95	1.45 1.20 0.75 1.25 1.15 0.95	1.05 1.85 1.20 1.65 1.60 1.80 } 1.7	Stopped Started
5										Smashed matte plates
6	8.20	0.198	1.00	0.25	5.41	(1) 2.0 (2) 3.15 (3) 2.3 (4) 2.0 (5) 2.8 (6) 3.9	1.35 1.15 1.05 1.2 1.2 0.95	1.35 1.75 1.25 1.2 1.2 0.95	1.15 1.7 1.25 1.9 1.6 1.95	
7	16.25	0.198	1.00	8.	13.5	(1) 3.9 (2) 3.8 (3) 4.7 (4) 3.7 (5) 4.4 (6) 4.6 (7) 4.6 (8) 4.5				
	16.28	Stopped			13.5					

Total ampere hours by account 13.5.

Weight of matte plates

Before heat	After heat	Loss.	Mean loss.	Meter.	Mean.
(1) 66.77	(1) 48.830	17.940	19.115	17.940	19.810
(2) 80.225	(2) 60.775	19.450			
(3) 60.445	(3) 41.360	19.090			
(4) 70.085	(4) 50.635	19.450			
(5) 58.910	(5) 39.100	19.810			
(6) 61.830	(6) 42.880	18.950			

Meter plates					
1st pair	(10)	87.595	87.545	0.050	Mean 0.033
	(12)	83.405	83.390	0.015	
2nd "	(16)	86.005	85.988	0.020	= 33 gms. in main set.
	(18)	75.017	74.970	0.047	∴ 1.213 gm. = 272 amp. hr.

13.5 amp. hrs. deposited 19.115 grammes of matte
1 " " 1.416 " " "
320 amp. hrs. deposited 1 lb. at 640,000 1 kw.

With carbon plates the average counteremf is 1.7 volts.
" CuO " " " 1.3 "

640,000 amp. hrs @ 1.3 volts = 832,000 Watt hrs = 832 Kwt hr @ 90% efficiency = 923.5 KWT hrs. mechanical. @ 0.776 ct = $7.16

640,000 amp. hrs. @ 1.7 volts = 1088,000 Watt hrs. @ 90% η = 1210. Kwt hrs. @ 0.776 ct. = $9.39

$x + y = 7289$
$2xy = 1817$
$x - y = 4444$

$2xy = 1817 \times 7289 = 13,244,113$
$4xy = 52,932,452$

$x^2 + 2xy + y^2 = 53,176,521$
$4xy \quad 52,932,452$
$x - y \quad 4444$
$197,069$

$2x = 7733$
$x = 3866.5$
$y = 3422.5$

1) $\frac{14.8}{15.5} \times 0.03 = 0.0299$ ∴ $= 1.00099$ –

Galv. 36446.5 each coil @ 66.

Legal 1 is greater ∴ Res. of 1 coil in bridge – $\frac{1.00099 \times 36446.5}{36466.5} = 1.00051$ –

As the ratio between the 2s, legal ohm does not check with that between themselves owing to the large added resistance, the link between the 2s and the 1s is supplied from the observation of the 30th on p. 19. namely that the mean 2s coil is 1.99566 of the 1s coil.

Starting from this point the ratio of the 2s being 1.000548

one 2s coil will be	1.99566×1.000274	$= 1.996198$	
the other 2s.	$1.99566 \div 1.000274$	$= 1.995121$	$1+2+2 = 4.99131$
5s	4.99131×0.996466	$= 4.973580$	$1+2+2+5 = 9.964899$
+1 10s	9.964899×1.005487	$= 10.019576$	$1+2+2+5+10 = 19.984475$
+2 10s	9.964899×1.003874	$= 10.003874$	$1+2+2+5+10+10 = 29.988349$
			$2 \quad 50$
20s	20.02275×0.99780	$= 19.978700$	49.966349
			49.977180

20 + 10 + 10 + 5 + 1 = 45.98586 of Bridge unit.

Establishment of the Resistances of a Standard Coil for Messrs Bergmann & Co. Mar. 24th 1890.

/15

Preliminary measurements.

Res. of both coils of Astatic Diff. Galv. by bridge measurement 7350 ohms
6 @ 73.5 × 0.03 × 6 = 13
7363
Leads 1
True res. of galv 7362

Passed current from 1 KHO cell through rheostat and the resistance to be compared. Adjusted galvanometer to be differential. Balance. Standard legal 1s @ 17.2°C. 1s in bridge @ 25.2°C.

Correct at 15.5
1.7 × 0.03 = 0.051 15s added to legal 1s at.

True res. 1.00051 1s. Legal.

Res. of 1s coil = $\frac{1.00051 \times 36466}{36466} = 0.99666$

Repeated test with greater care on 25th Mar. 1890.

Res. of two compounds galv coils in series 7289 –
in parallel 1817 –

Having balanced coil when in series, ascertained that 9s had to be added externally to the coil already furnished with a spool in order to balance. Removed spool which had 22.7s of 9.5. wire and replaced it after filling with 31.7s of copper wire silk covered 0.002" wound double. Instrument then balanced for both series and multiple.

Res. of coils in series by 3rd table bridge 7289 s in parallel 1817s.

1) Compared 1s in 1st table bridge with Standard Legal s. commutator, with pressure leads wound round its electrodes just above the mercury cups.

Balance with 2s added to legal s aside. Temp Std 18.8°C. Bridge 20.7°C. } Res. of 1s in bridge = 1.00044

2) Legal s against 2s (1st coil) in bridge
3619s added to 2s side

No. of Obs.	Comparison before		Temp. of Legal s	Temp. of Bridge	Res. of one coil temp. coil of Galv	Res. added for balance	} to		Ratio	Res. in terms of Legal s	
1	Legal 1s	1s in Bridge	18.8°C.	20.7°C.	36446.5	2s	Legal Std.	36466.5	1.000549 0.999451	1.00044	
2	. .	1st 2s . .	-	. .	-	3619s	2s	7268.5	1.993	1.99497	
3	. .	2nd 2s . .	.	. .	-	3622s	"	7266.5	2.00622		
4	1st 2s	2nd 2s . .	19.0°C.	. .	.	2s	2nd 2s	36466.5	1.000549		1.00066
5	1, 2, 2,	5s . .		. .	-	13s	1 2 2	36575.5	1.003567		0.996466
6	1, 2, 2, 5	10s 1st		. .	-	20s	10s	36466.5	1.005487		
7	1, 2, 2, 5	10s 2nd		. .	-	14s	2nd 10s	36585.5	1.003874		
8	10s 1st	10s 2nd		. .	.	2s	1st 10s	36485.5	0.99903		0.998363
9	10.10	20s		. .	.	8s	10 & 10	36525.5	0.99780		
10	combined 5Ω	5Ω coil		. .	.	4s	combined 5Ω	36485.5	0.998904		
11	Legal 1s	1s in Bridge	19.2	21.0°	-	2s	Legal Std.	36466.5	1.000549		

Number of Vibrations (complete) for different standard pitches

Normal	256 do.
French	258.7
German	261.6
English	270.2

Bar: observation 74·61 cm @ 77°·F

Index error ·044

74·654

Temp. corr. ·343

Corrected reading 74·997 @ 0°C.

Res. of both coils diff. galv. 5·450 T.B. 25·9°C 1 mm/cm = 2·750 each coil

Bar: observation 74·59 cm @ 70°·F 22 o'clock ~~Bar observation~~

Index error ·044

74·634

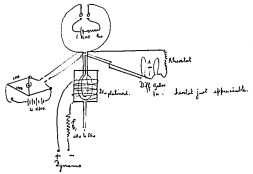
Temp. corr. ·290

Corrected reading 74·344 @ 0°C.

Mean Bar. corrected reading @ 0°C 74·33

increasing 0·002, each reading

At 10·27 current in heating coil interrupted. Res. of coils fell 0·10 before change of direction noticed by J. at Cottesmore.



$22 \times 0.00016623 = 0.0045506$ $\quad \frac{1}{1.0045506} = 0.99547$

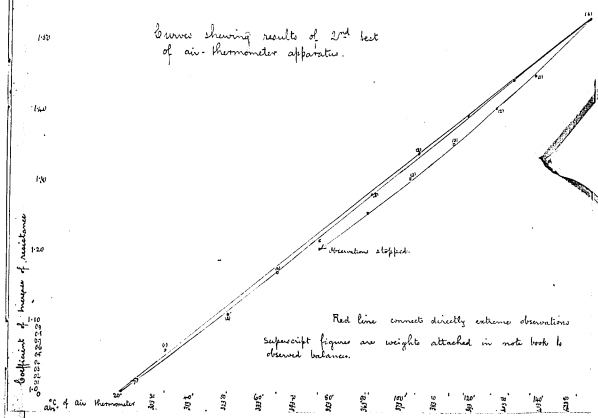
Constants of tube approx 75°; of capillary tube about 0·3 $\therefore n = \frac{75}{0.3} = 250$

$$T_{ab} = \gamma t \left\{ 1 + (V-1)(3\beta t + \kappa) \right\}$$

where $\kappa = \frac{t}{n}$ and $V = \frac{P}{p}$

res. of a to	10·130
" " b to	10·134
" " a to	20·231
2 a to b to	40·495
a to b to	20·2475
mean	20·231
interior bulb b	0·0165
other bulbs	0·015 each say.

Curves showing results of 2nd test of air-thermometer apparatus.



Experiments on the Temperature-Coefficient of Copper.

2nd trial up to 15·0°C of temp. elevation.

The only change made in the experiment was the introduction of the hand-beat differential galvo. to test quickly the resistance ratio of the two coils. This was found to be a very convenient and accurate arrangement as the following tests will shew.

At 20.30 the capillary tube was scaled. Temp. of air bath 21.16°C Bar. 74·844

Obs. No.	Time	Temp. of Hot	Temp. of Bridge	Observed res. of arm a	Corrd. 0·330 deducted	Observed res. of b or c	Diff. 0·326 deducted	Observed res. of a	Time 2·339 deducted	Balance Tr. to	Ratio Hot/Cold	Calthermometer reading	Rise above Zero	Temp. of Hot
1	20·30	21·8	24·7	10·660	10·330	10·660	10·334	20·560	20.231 20.564	17	1·00624	12·023		22·0°C
2	21·28	21·8	25·5			0·006		20·690	21·28	10	1·00367	14·986	2·963	22·0
3	·33							22·90	22·37			19·439	7·695	21·9
4	·38	21·8						23·02	23·691	8		23·000	10·977	21·8
5	·42							24·94	24·61	5	1·00183	25·970	13·947	21·8
6	·50	21·6	26·3					26·23	25·95	5	1·00183	29·618	17·595	21·8
7	·52							27·48	27·15			32·922	20·899	21·8
8	22·01							28·58	28·25			36·444	24·421	21·9
9	·10							29·66	29·33			39·664	27·641	22·0
10	·15	22·2						30·75	30·42	2	1·00073	43·032	31·009	22·1
11	·25		26·6					31·37	31·04	2	1·0000	45·103	33·080	22·2
12	·34	20·8	26·2					29·50	29·47	8	1·0030	41·180	29·157	22
13	·37							28·83	28·50	10	1·00367	38·430	26·407	21·8
14	·40							27·77	27·44			35·388	23·365	21·6
15	·45							26·74	26·41	11	1·0040	32·292	20·269	21·4
16	·51							25·75	25·42	11	1·0040	29·386	17·363	21·2
17	3·00	20·35	25·9					24·70	24·37	11	1·0040	25·962	13·939	21·0
								25·1·85	246·587			324·438	238·5·87	
								5·093	24·6·0				32··31	
								1·1·1·2·33	1·1·1·2·33					

Obs. No.	Corrected Calthermometer reading	Total run from 0°C	Coeff. r	Obs. temp. of air at time of reading	Calculated corr. temp. of air	Temp. by thermom.	Rise of temp. °C	Resistance hot	Coeff. of hot	Coeff. per hour	Res. of hot. Rise as calculated	True res. of hot. Rise	(R−1)×100=p	Correction factor
1								0·000	1·00		0·03	20·201		1·0002
2	2·950	74·311	1·000	29·46	29·46	21·6		0·00075	1·0559	0·00758			0·00029	1·00010
3	7·381	77·263	1·0597	29·46·65	30·6·35	33·35	11·75	0·0040	1·11157	·00379			0·00173	1·00047
4	10·927	81·696	1·0994	29·46·73	32·6·03	51·0	29·4	0·00046	1·1710	·00392			0·00054	1·00061
5	13·8814	85·246	1·1267	29·46·8	33·8·2	65·2	43·6	0·00075	1·2165	·00391			0·00138	1·00153
6	17·5·15	88·846	1·1870	29·46·86	35·0·0	77·0	55·4	0·00941	1·2927	·00404			0·000177	1·00211
7	20·805	91·838	1·2359	29·46·93	36·4·5	91·5	69·9	0·00812	1·3420	·00412			0·000208	1·00232
8	24·310	95·146	1·2800	29·46·98	37·7·57	104·6	83·0	0·00830	1·3964	·00457			0·000241	1·00255
9	27·516	98·637	1·3274	29·5·06	39·1·7	118·7	97·1	0·00850	1·4498	·00493			0·000273	1·00277
10	31·269	101·865	1·3705	29·5·12	40·4·5	131·5	109·9	0·00866	1·5036	·00524			0·000305	1·00297
11	32·930	105·200	1·4158	29·5·19	41·7·9	144·9	123·3	0·00876	1·5543	·00566	0·045	31·0	0·000336	1·00309
12	29·025	107·263	1·44434	29·5·22	42·6·2	153·2	131·6	0·00856	1·5467	·00394			0·000238	1·00216
13	26·287	103·360	1·3909	29·5·13	41·0·5	137·5	115·9	0·00812	1·4987	·00389			0·000260	1·00236
14	23·285	100·624	1·3544	29·5·10	39·9·6	126·6	104·0	0·00782	1·3560	·00383			0·000230	1·00156
15	20·177	97·598	1·3134	29·5·06	38·7·5	114·5	92·9	0·00809	1·3054	·00379			0·000200	1·00139
16	17·264	94·518	1·2719	29·4·98	37·5·2	102·2	80·6	0·00893	1·2565	·00372			0·000172	1·00110
17	13·937	91·637	1·2330	29·4·92	36·3·6	90·6	69·0	0·00718	1·2066	·00369			0·000138	1·00089
		88·222	1·1872	29·4·87	35·0·0	77·0	55·4							
	320·050	583·637				1440·95	273·75							
	74·311	188·976					387·2							
	394·361	394·661					1640·95							
	3·300													

The calthermometer is graduated for accuracy at 0°C its coefficient of expansion being 0·0000187 per °C (assumed by the Makers). The correction to apply to the mercury column is therefore 0·0000181 − 0·0·0000187 = 0·0001623 per °C.

No time lag could be discerned between the removal of the heat supply and the falling of the resistance. In fact the fall in resistance could be detected several seconds before the mercury column showed signs of rise.

The capillary tube was not topped, in this series.

In the case of this tube whose approximate contents was 70 c.c. with a tube whose capacity to the index was calculated to be 0.2 c.c. $n = 70/0.2 = 350$

with τ assumed at that of air in 25° + 273 = 295

and T taken at 200 + 273 = 473

The correction factor for the cooling of the index tube is $\left(\frac{473}{295}\right)^2 = \frac{223729}{103250} = 2.2$ " $\frac{1}{1.03 \times 10^{-5}} = 0.9685 \times 10^{-5}$

At present 3β will have to be taken at the usual value 0.000025

and $T = T\{1 + T(2.5 \times 10^{-5} + 0.9685 \times 10^{-5})\}\{1 - t \times 2.5 \times 10^{-5}\}$

$= T\{1 + T(3.469) \times 10^{-5}\}\{1 - t \times 2.5 \times 10^{-5}\}$

$= T\{1 + T \times 3.469 \times 10^{-5} - t \times 2.5 \times 10^{-5}\}$

t being 22 + 273 = 295

$t \times 2.5 = 737.5 \times 10^{-5} = 7.375 \times 10^{-3}$

$= T\{1 - 0.007375 + 0.000003469\,T\}$

$= T\{0.992625 + T\,0.000003469\}$

$= T\{0.992625 + T^2 \times 0.000003469$

with T = 100 + 273 = 373 $T = 375$ correction 2°

T = 200 + 273 = 473 = 477.3 " 4.3°

T = 300 + 273 = 573 = 580 " 7°

The most convenient form of the general formula is

$$\frac{T}{\text{abs}} = \frac{Pt}{p}\left\{1 - 3\beta t\right\}\left\{1 + \frac{Pt}{p}\left(3\beta + \frac{1}{n\tau}\right)\right\}$$ all temps absolute.

If $\tau = t$ this becomes

$$= \frac{Pt}{p}\left\{1 - 3\beta t\right\}\left\{1 + \frac{Pt}{p}\left(3\beta + \frac{1}{nt}\right)\right\}$$

Let $P = rp$

$$T = rt\left\{1 - 3\beta t\right\}\left\{1 + 3r\beta t + \frac{r-1}{n}\right\}$$

$$= rt\left\{1 + \frac{r}{n} + 3\beta t\left(r - 1 - \frac{r-1}{n}\right)\right\} \quad \text{If } 3\beta = 2.5 \times 10^{-5} = rt\left\{1 + \frac{r}{n} + 2.5 \times 10^{-5}(r - 1 - \frac{r-1}{n})\right\}$$

$$= rt\left\{\left(1 + \frac{r}{n}\right)(1 - 3\beta t) + 3\beta t r\right\} \quad \text{when } n = \infty$$

$$= rt\left\{1 + 3\beta t(r-1)\right\} \quad \text{If } 3\beta = 2.5 \times 10^{-5} = rt\left\{1 + 2.5 \times 10^{-5}(r-1)\right\}$$

$$T_{\text{abs}} = rt\left\{1 + \frac{r-1}{n} + 2.5 \times 10^{-5}(r-1)\right\}$$ if $3\beta = 2.5 \times 10^{-5}$ since $\frac{r}{n}$ is very small or.

when $n = \infty$, $= rt\left\{1 + 2.5 \times 10^{-5}(r-1)\right\}$ Let $\frac{1}{n} = K$

$rt\left\{1 + (r-1)(3\beta t + K)\right\}$

Calculation of the Correction for the Indications of an Air-Thermometer affected by expansion of the bulb and by the cooling of remote portions of included air.

Let V be the volume of the bulb at normal temperature.
" v " " " capillary tube
" V' " " " bulb at the temp. T attained.
" t " " temp. of the included air uniformly at normal.
" T " " true temperature reached uniformly in the bulb.
" τ " " " " of the air in the capillary tube.
" P " " pressure reached at temp. T (abs)
" p " " initial pressure at normal temp. τ.

Then
$$T = \frac{PV'}{\frac{p}{t}(V + v) - \frac{Pv}{t}}$$

$$= \frac{PV\{1 + 3\beta(T-t)\}}{\frac{p}{t}(V+v) - \frac{Pv}{t}} \quad \text{if } V = nv$$

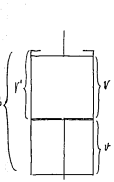
$$= \frac{Pn\{1 + 3\beta(T-t)\}}{\frac{p}{t}(n+1) - \frac{P}{t}} = \frac{P\{1 + 3\beta(T-t)\}}{\frac{p}{t}\left(\frac{n+1}{n}\right) - \frac{P}{nt}}$$

$$= \frac{P(1 - 3\beta t)}{\frac{p}{t}\left(\frac{n+1}{n}\right) - \frac{P}{nt} - 3\beta P} = \text{when } n \text{ is a large number}$$

$$= \frac{P(1 - 3\beta t)}{\frac{p}{t} - P\left(3\beta + \frac{1}{nt}\right)} = \frac{P(1 - 3\beta t)}{\frac{p}{t}\left\{1 - \frac{Pt}{p}\left(3\beta + \frac{1}{nt}\right)\right\}} = \frac{\frac{Pt}{p}(1 - 3\beta t)}{1 - \frac{Pt}{p}\left(3\beta + \frac{1}{nt}\right)}$$

$$= \frac{P}{p}t\left\{1 + \frac{Pt}{p}\left(3\beta + \frac{1}{nt}\right)\right\}(1 - 3\beta t) = \frac{P}{p}t(1 - 3\beta t)\left(\frac{Pt}{p}\right)^2\left(3\beta + \frac{1}{nt}\right)(1 - 3\beta t)$$

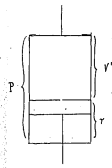
Proof: Let a cylinder be divided horizontally by a diaphragm having an orifice closed by a valve but capable of being opened at will. Let the upper cylinder be of length V' and let the piston be placed initially to enclose V. Let the lower cylinder be closed by a piston just beneath the diaphragm and a back distant v. Let the valve be closed. The temp. be t uniform throughout and the pressure p also uniform.



Then let the upper chamber be raised to the temp. T and the lower to the temp. τ. V will then increase to the limit V' which v will remain constant. The pressure Π in the upper cylinder will become $= \frac{RT}{V'}$ where R = gas const.

The pressure π in the lower cylinder " " " " " π will be the greater suppose. Now open the valve in the diaphragm. Air will descend into the lower chamber until the pressure is uniform in both and = P.

The air beneath the lower piston will now occupy a volume $\frac{v\pi}{P}$ and the volume above it occupied by air from above $= v\left(\frac{P - \pi}{P}\right)$. Had this air retained its normal temperature T, its volume would have been $v\left(\frac{P-\pi}{P}\right)\frac{T}{t}$ and the pressure above will have fallen to a degree proportional to that amount, or



$$\frac{p}{\Pi} = \frac{V'}{V' + v\left(\frac{P-\pi}{P}\right)\frac{T}{t}} \quad \therefore PV' + Pv\frac{(P-\pi)T}{Pt} = \Pi V'$$

$$\therefore PV't + P^2vT - Pv\pi T = \Pi PV't$$

$$\therefore PV't + Pvt - \pi vT = \Pi V't$$

Eliminate π and Π. $\frac{\Pi V'}{P} = \frac{pV}{t}$ & $\frac{\pi v}{P} = \frac{pv}{t}$

$\therefore \Pi = p\frac{V}{V't}T$ $\pi = p\frac{v}{t}$

$$\therefore PV't + Pvt - \frac{pvvT}{t} = \frac{pVTt}{t}$$

$$\therefore PV't + Pvt - \frac{pvTt}{t} = \frac{pVTt}{t}$$

$$T(Pvt - pvt - pVt) = -PV't\tau$$

$$T\{pt(V+v) - Pvt\} = PV't\tau$$

$$T = \frac{PV't\tau}{pt(V+v) - Pvt} = \frac{PV'}{\frac{p}{t}(V+v) - P\frac{v}{t}}$$

Required the Winding for two new cores on the present form of Electromagnetic Rockdrill.

The new magnets are to be 8" (20·3) long and 3·25" (8·22) in diam. The surface of each when wound to a depth of ¼" will be $\pi \times 11{\cdot}2 \times 20 = 704$ sq. cm. and allowing 10 per watt = 70 watts on each. If operated from a P.D. of 50 volts all 3 coils in series the P.D. on each = 16·67 and the current will be over 1. amp. As this will be excessive for the central coil it will be better to employ 20 sq. cm. per watt = 35 watts per coil = $\frac{35}{16{\cdot}67} = 2{\cdot}1$ amp. The res. of each coil will be $\frac{16{\cdot}67}{2{\cdot}1} = 7{\cdot}94\Omega$ (hot) = $\frac{7{\cdot}94}{1{\cdot}12} = 7{\cdot}052\Omega$ cold. The winding space is

$$20 \times \frac{\pi}{4}(11{\cdot}2^2 - 8{\cdot}2^2) = 15{\cdot}708\,(125{\cdot}44 - 67{\cdot}24) = 15{\cdot}71 \times 58{\cdot}2 = 914{\cdot}4 \text{ c.c.}$$

$$d = -0{\cdot}02 \pm \sqrt{\left\{0{\cdot}0004 + 0{\cdot}00153\sqrt{\frac{914{\cdot}4}{7{\cdot}05}}\right\}}$$

$$+ 0{\cdot}00153\sqrt{130{\cdot}1}$$

$$+ 0{\cdot}07745$$

$$\sqrt{0{\cdot}01785}$$

$$+ 0{\cdot}1336$$

$$= 0{\cdot}1316 \text{ mm.} = 0{\cdot}052'' = \#16 \text{ B.\&S.} \text{ or } \#18 \text{ B.W.G.}$$

#18 B.W.G. has 1·69 lbs. per ohm = 11·83 say 12 lbs. of #18 B.W.G. magnet wire on each core.

Test of the specimens of Safety Conduit Tubing that have been submerged in a tank since 11th Jany. 90

25. II. 90.

Bonet and Simple minor hipot galv. not solder.
#1 Apollo cable no. S. 100,000 – 187 diam.

Specimen #1	⅝" diam.	50 cells no S.	157 – 162 +	about 4 a abs.	
# 2	⅝"	bad 1	17 + 20 –		
# 3	1½"	50	345 – 350 +		2·5Ω
# 4	·3"	short piece 50	18 ±		50Ω
		but bad			

Tried to improve these readings by recovering the ends of these tubes with paraffine wax.

Succeeded with #1 in bringing deflection down to 110 ± = 8·5 Ω abs., but not with the other. On careful examination the faults were found to exist at particular places in each tube, as following example will show:—

No 3. in air after coating with paraffine wax on ends.
Drawn slowly through wet cotton waste in cat, local deflection.
Dried again and submerged.

1st ½ d.	submerged in tank	50 cells no S.	± 3 diam
1st 3½d.	–	–	± 70 –
almost wholly	–	–	+ 350 – of only above water, showing fault not in the seal.

Sent following report to Mr. E. H. Johnson of Edison & Boston.
"Specimens previously reported on now offers eight and half meghm
Some specimens failing others very fair. All submerged for seventy days.

Test of same specimens on 26th April 1890.

Specimen #1 by bridge ⅝" diam. 2·5Ω
short piece 1" in cat – 0·6Ω

Other all bad.

But of one piece of 1¾" I found it to contain 250 c.c. of clear water. Ascertained that the insulation was bad all through this piece although the section looked good. Sent a sample and a report to Mr. Johnson.

No correction is made to the appr res of the galv. coils for temp. because all the resistances employed are affected by w. like error.

		Sum
1ω in bridge balance as unity	1·000 000	
2ω #1 . . .	1·995 39	
2ω #2 . . .	1·995 39	1·991 32
5ω	4·973 74	9·965 06
10ω #1 .	10·021 96	19·9 87 02
10ω #2 .	10·011 12	29·9 98 14
20ω	20·016 75	50·0 14 89
50ω	49·974 13	99·989 02

20 + 10 + 10 + 5 + 1 = 46·02257

1ω @ 15·5 = 0·0003 × 7·4 = 0·00222 at 22·9°C

= 1·00222ω

1·00222 × 0·999185 = 1·001463 ω

If s be the res. of the std. ω at a given temp.
Then the res. of the bridge unit = 0·999 32 s.
and the " " " 46 ω = 46·0047 × 0·999 32 s. = 45·97345 s.

The res. required being r
" " of our galv. coil g
" " for balance x

$$\frac{g+x}{g} = \frac{r}{45\cdot97345\,s}$$

$$x = \frac{gr}{45\cdot97345} - g$$

$$= g\left(\frac{r - 45\cdot97345\,s}{45\cdot97345\,s}\right)$$

or

$$\frac{g}{g+x} = \frac{r}{45\cdot97345\,s}$$

$$\frac{g+x}{g} = \frac{45\cdot97345\,s}{r}$$

$$x = g\left(\frac{45\cdot97345\,s}{r} - 1\right)$$

$$= g\left(\frac{45\cdot97345\,s - r}{r}\right)$$

Comparison of Bridge B with Legal Ohm.

30 III. 90

Legal ohms immersed in water. Temperature very fairly uniform for several hours. Actual Diff. galv. quite differential bo added to spark side + subtd.

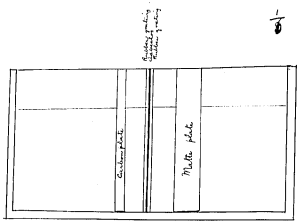
No. of Obs.	Temp. of Standard Ohm	Res. of Standard Ohm	Temp. of Bridge	Resistance compared		Balance res. added	to the	Res. of Galv. coil on one side	Res. of added side	Ratio	Res. of bridge in ω
1	23°C.		22·9°C	Legal 1ω	1ω in this {2 in parallel	3ω	10·50	Legal Std.	3677·5	3680·5	0·999185	1·00000
2	Std. Ohm			" 1ω				" "	"	3688	0·997017	0·997830
3	#1			" 1ω	1ω . 6.*	2ω		" "	"	3680·5	"	
4				2ω #1	2ω #2	1ω		2ω #2	"	3678·5	1·000271	(1·995739) #2 (1·995739) #1
5				1+2+2	5ω	13ω		1+212	"	3690·5	0·994477	4·973714
6				1+2+2+5	10ω #1	21ω		10ω	"	3698·5	1·005710	10·021196
7				1+2+2+5	10ω #2	17ω		10ω	"	3696·5	1·004622	10·011112
8				10ω #1	10ω #2	3ω		10ω #1	"	3680·5	1·000816	(1·000883 by wt from 1-7)
9				10ω #1	20ω	6ω		10ω #1	"	3683·5	0·999104	
10				Σ 50	50	3		Σ 50	"	3680·5	0·999185	

* Change made here under condition of connections necessary to throw the 2 2ω coils in parallel.
The 2 2ω coils in parallel test 0·997017 by ω and the 1ω coil test 0·999185 by ω
so that " " " " " 0·997830 1ω coil
" " test 2ω " supposed equal 1·99566
one (#2) 2ω = 1·000271 of the other (#1)
#2 = 1·0001355 × 1·99566 = 1·995930
#1 = 1·99566 ÷ 1·0001355 = 1·995389

24th Comparison of results of tests on two different occasions 30th March

No.	Coil	Temp.	Res. added to coil	Ratio to Bridge 1ω	Res. of 46ω		Coil	Temp.	Res. added	Ratio to Bridge 1.	Res. of 46ω	Mean Res. of 46ω
1	1ω	20·7°C		1			1ω	22·9°C		1.		
2	#1 2ω			1·995121			2ω #1			1·995739		
3	#2 2ω		+2	1·996198			2ω #2		+1	1·995993		
4	5		−13	4·97358	45·91516		5ω		−13	4·973714		
5	#1 10		+20	10·019576			10ω #1		+21	10·021196	46·02257	46·00471
6	#2 10		+14	10·008597 .003174			10ω #2		+17	10·011112		
7	20		−4	19·984110 19·987600			20ω		−6	20·01675		
8	50						50ω			49·97413		

At temp. of 22·9°C. the 1ω in bridge = 0·999185 of legal ω at same temp.
20·7°C " " " " = 0·994451
Mean = 0·999318



Longitudinal section of bath.

If A be the area of matte in sq. ft
" d " " density of current in amp. per sq. ft
Ad will be the total current flowing and
$\frac{640000}{Ad}$ = time in hours required to dissolve 1 ton.
" r be the res: of one sq. ft
$\frac{r}{A}$ = total resistance
and Ad^2r = C^2R = total rate of working
640,000 dr = total number of Watt hours
640 dr = " " " " " electrical
800 dr = " " " " " mechanical @ 80%

The res: is 0.234 for ⅓ sq. ft = 0.157 " for sq. ft
126 d = total number of Watt hrs mechanical for this bath
97.8 d ditto " " " ditto " " " "
$8 d appx.

Experiment upon Electrolysis of Matte.

A large bath of NaCl solution in water was prepared of dimensions shown, and having at its center a transverse partition of asbestos 0.25" (1/40") thick. Sp. g. of solution 1.16 @ 17°C. The matte plate was a casting 11" (27.9) × 11" (27.9) × 2.25" (5.7) = 272 c.in. (4460 cc) weighing 700 oz (26.5 kgm) sp. g. of 6.05.

The matte plate cracked up and disintegrated so rapidly that it spoiled the test. A copper voltameter was in circuit. The depth of solution was 8" (20) so that the area of matte exposed was about ⅓ of 1 sq. foot, and the distance between the carbon and matte plates was 4½" (11.4). The carbon plate fitted the bath with fair accuracy and was 1" (2.5) thick.

The following observations were made as soon as the current had fairly started.

No of Obs:	Time	Obsch	Amperes	Lamps	PD across bath	Res: by measure	PD across 1 ohm res:	EMF	Amperes per sq foot	Approximate cost for consuming 1 ton	Total cost per ton
1	15.0	0.415	2.08	4	1.65	0.234	0.487	1.16	3	$ 3.	$ 10.35
2	.05	0.590	2.95	6	1.95		0.690	1.26	4.5	4.60	11.75
3	.07	0.752	3.78	8	2.20		0.884	1.32	5.67	5.55	12.85
4	.09	0.915	4.60	10	2.37		1.08	1.29	6.9	6.75	14.10
5	.11	0.53	5.3	12	2.53		1.24	1.29	7.95	7.77	15.12
6	.15	0.59	5.9	14	2.70		1.38	1.32	8.85	8.65	16.00
7	.17	0.645	6.5	16	2.82		1.52	1.30	9.75	9.53	16.88
8	.18	0.705	7.1	18	3.0		1.66	1.34	10.65	10.42	17.77
9	.19	0.763	7.6	20	3.1		1.78	1.32	11.4	11.17	18.52
10	.20	0.815	8.2	22	3.2		1.92	1.28	12.5	12.22	19.57
11	.22	0.851	8.5	24	3.32		1.99	1.33	12.75	12.46	19.81
12	.22	0.91	9.1	27	3.48		2.13	1.35	13.65	13.35	20.70
13	.23	0.85	8.5	24	3.32		1.99	1.33	12.75	12.46	19.81
14	.24	0.815	8.2	22	3.24		1.92	1.32	12.3	12.02	19.37
15	.25	0.766	7.7	20	3.12		1.80	1.32	11.55	11.30	18.65
16	.26	0.705	7.1	18	3.0		1.66	1.34	10.65	10.41	17.76
17	.27	0.641	6.4	16	2.82		1.50	1.32	9.6	9.39	16.74
18	.28	0.588	5.9	14	2.71		1.38	1.33	8.85	8.65	16.00
19	.29	0.527	5.3	12	2.55		1.24	1.31	7.95	7.77	15.12
20	.30	0.445	4.5	10	2.37		1.05	1.32	6.75	6.60	13.95
21	.31	0.371	3.7	8	2.2		0.87	1.33	5.55	5.43	12.78
22	.32	0.296	2.2	6	2.0		0.7	1.30	4.5	4.40	11.75
23	.34	0.217	2.2	4	1.8		0.52	1.28	3.3	3.23	10.55

640,000 amp hrs: dissolve 1 ton of Matte.
at 1.33 volts = 853000 Watt hrs
= 853 kilowatt hrs electrical
= 947 " " mechanical @ 90% eff. @ 0.776 = $7.35

Adjustment of a Standard 46·46ω Coil for Messrs Bergmann &c:

1. IV 90.

#1 coil in water up to within 1 cm of neck. Temp. of water 19.42

Res: of galv: 7367ω by bridge w/o/ms T.B. 25·5°C leads 2ω = 7365ω.

allowing for excess of bridge temp. each component coil = 3685ω

Temp of standard bridge 23·4°C.

46ω unplugged in the bridge will offer 45·973 × 1·00237 = 46·0822ω

46·46ω @ 70°F (21·1°C) = 46·155ω @ 19.4°C

∴ res: to add to coil side = $3685\left(\frac{46\cdot155 - 46\cdot082}{46\cdot082}\right) = 5\cdot8\omega$

Coil adjusted until balanced at 6ω

#2 coil similarly situated. Final measurement

Res. of each component galv coil 3685ω. Temp. of water surrounding coil 20.95

46ω unplugged in the bridge = 45·973 × 1·002446 = 46·0865

46·46ω @ 21·1°C = 46·4059ω @ 20.5

∴ res: to add to ~~bridge~~ coil side = $3685\left(\frac{46\cdot4059 - 46\cdot0865}{46\cdot0865}\right) = 25\cdot6\omega$.

Coil adjusted until balance between 25 + 26ω.

Thermometer used was Standard #1.

Check by Bridge on 4th table.

Coil #1 @ 20.9°C. 1000/100 leads

48·45ω
2·02
46·43 @ T.B. 27·5
·01
46·44ω = coil @ 21·0°
·03
46·47ω @ 21·1°C.

Coil #2 @ 21·1°C 1000/100

48·47ω
2·02
46·45ω @ TB 27.5
·01
46·46ω @ 21·1°C.

Calculation of wire for new Electrodynamometers

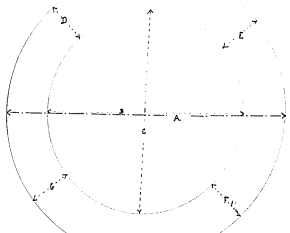
In the present dynamometer 70 turns give 360° with 17·5 amp. For 1000 volts the current should not exceed 20 milliamperes say 17·5 milliamperes so for the fact there must then be 70.000 turns instead of 70. The thickness of the coil is 1·25" and its depth 0·5". The diam of the present wire (covered) is 0·11". It will then be necessary to use the finest silk covered wire for the interior bobbin.

For 100 volts the current should not exceed 50 milliamperes or $\frac{1}{350}$th of that in the present coil. The diameter of the wire should then be reduced 18 times or 0·004" but as this coil will have enormous self induction, it will be necessary to use stronger current and external resistances.

The highvolt dynamometer can have a diam of 0·033" covered = 0·030" # 22 wire B.W.G. and the low volt dynamometer 0·055" covered = 0·048" # 19 wire B.W.G. d.c.

The external coil of the voltmeter for 1000 volts will be 2 layers of 10 turns.

The external coil of the voltmeter for 50 volts will be 5 turns in 1 layer of



Permeability Measurement of Iron Samples.

Ring of polished Mitis iron, and a larger ring of cast iron supposed to contain 1/10 part of air by weight in 1/14 of metal or 12.287.

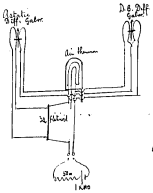
No.	Composition	A	B	C	D	E	F	G	Mean DEFG.	Wt in air	Wt in H2O	Volume by H2O	Volume by calculation
1	Iron	25.2	~~25.0~~	16.9	3.15	3.1	3.2	3.2	3.163				
2	Mitis	18.2	16.05	16.05	1.12	1.123	1.17	1.125	1.122	4.079	3.529	550	544.85

No.	Total No. of turns	Total primary turns	Total secondary turns	Mean circumference cms.	Primary turns per cm.	Area of circle section sq. cms.	
1	1408	1025	~~1080~~	69.28	14.79	7.858	
2	1053	~~818~~	335	53.80	~~1.25~~ 15.21	1.019	7.4

No. of Obs.	(1) Time	(2) Sec. galv.	(2) Ballistic	(2) Current amp.	2) No. of Obs.	2) Mean throw	2) Probable error	2) Res. of galv. cct.	2) Res. in main cct.	2) Total res. in sec. cct.	2) $\frac{2\times 10^{10}}{2\times 2\pi}\times\frac{0.05}{3}$	H	φ
1	14.15	14.07	~~0.019~~	0.190	5	29.7	± 0.7	20,200	–	20,200	~~2.4×10⁻⁴~~	$\frac{2.3\times 10^{-3}}{5.19}$	3.811×10⁻³
2	27	26.15	0.061	0.172 0.309	7	57.0	± 0.6				7.776×10⁻³	4.11	7.31
3	55		0.120	0.606	6	77.0	± 0.4					10.12 8.09	9.88
4	15.08		0.244	1.08	4	92.5	± 0.25					11.11 14.42	11.87
5	17		0.202	1.526	7	44.1	± 0.5					25.38 26.38	12.66
6	30		0.51	2.576	6	48.8	± 0.5					32.13 34.39	14.01
7	38		0.76	3.84	4	57.1	± 0.4					41.10 51.29	14.67
8	45		0.025	5.178	2	55	± 1.6					62.10 69.7	15.79
9					3	61.33	± 2.6						15.40
10	48		1.615	8.16	2	128.5	± 1.2					127.0 107.9	16.48
11	56		2.39	12.07	2	135	± 1.7					132.0 161.1	17.32
12	1.00		3.210	1.061	3	92.7	± 0.5					17.41 14.16	11.89

No. of Obs.	1) No. of Obs.	1) Mean throw	1) Probable error	1) Res. of galv. cct.	1) Res. of main cct.	1) Total res. in sec. cct.	1) $\frac{2\times 10^{10}}{2\times 2\pi}\times\frac{0.05}{3}$	H	φ	1) L	μ	3) L	3) μ
1	6	16.3	± 0.4	20,200	0	20,200	6.801×10⁻³	3.53	1,930	233	66	3741	1175
2	7	77.2	± 0.5				8.166×10⁻³	5.76	8,664	1103	192	7176	1860
3	7	204.4	± 1.4				= 5.552×10⁻³	11.27	22,940	2920	259	9,700	1889
4	6	322	± 3.0					20.08	36,140	4600	229	11,650	8.08
5	5	172.3	± 0.2		25,000	45,200		28.37	43,270	5507	194	12,430	6.80
6	6	221.3	± 1.4					47.90	55,570	7072	148	13,750	2.00
7	6	249.9	± 1.2					71.4	62,720	7982	112	14,400	2.87
8	4	275	± 2.8					96.28	69,060	8790	91.3	15,500	1.78
9												15,120	2.19
10	2	321	± 10					151.75	80,600	10260	67.6	16,180	1.18
11	2	225	± 2.4		50,000	70,200		224.4	87,750	11,170	49.8	17,000	1.49
12	3	329	± 2.6					19.73	36,930	4700	23.8	11,670	1.86

No. of Obs.	EME	Body	q.	No. of Obs.	Before Inc. Mean throw	Prob. error	No. of Obs.	After Dec. Mean throw	Prob. error	Accepted mean throw	value of 1 div. in q.	
1	1.431	1f	1.431×10⁻⁷	6	173.7	± 0.16	10	176.8	± 0.6	175.2	8.166×10⁻⁷	
2				~~10~~	~~176.8~~	±						



Res: of Ast. Galvo both coils 7205 ω. T.A. 18°.0
heads
7203 ÷ 2 = 3601.5

. . D.A. . both coils 5332
2
5330 ÷ 2 = 2665.

Both galvanometers differentiated to observation.

Barometer reading at time of reading 76·22
index corr ·0444
76·2644 @ 20·5

0·0000017 × 20·5 = 0·000349
76·2644 + 1·000349 = 76·999
Temp. corr 0·265

Res: of Ast. Galvo. after test 7261 ω.
heads 2
7259
coil cut 3629·5 ω.

Barometer reading 21·30 76·27
·044
76·314 @ 21·1°
·269
76·045 @ 0°C

0·0001623 × 15·6 = 0·0025323
0·0001623 × 17·8 = 0·0028890
Mean 0·0027111

$k = \frac{1}{200} = 0·005$

$t = 300$

$\beta = 2·5 \times 10^{-5}$

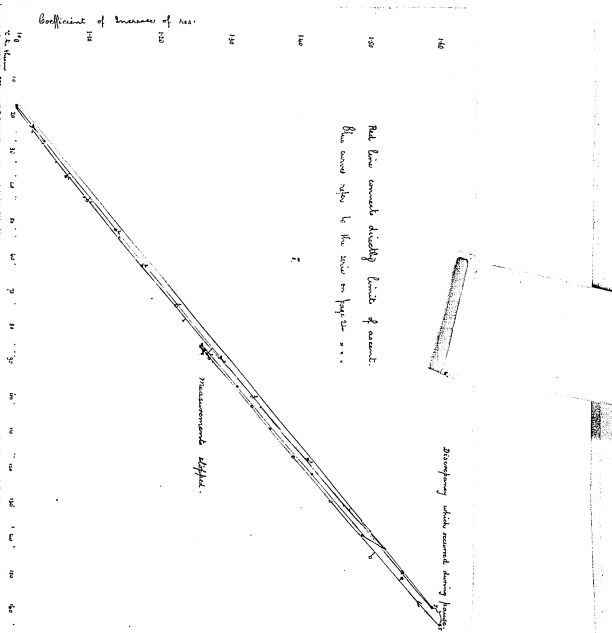
$\beta t = 7·5 \times 10^{-3} = 0·0075$

βt corr 0·0115

Res: of galvo at close of test 7261
2
2)7259
3629·5

3617·25 × 21 = 75962·25

1·605	1·255
1·597	1·263
1·601	1·262
1·601	1·262
4)6·404	4)5042
1·601	1·261



Sunday) 23 IV 20

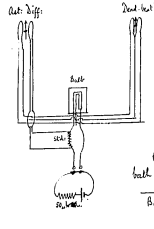
Experiments on the Temperature-Coefficient of Copper.

In this series, the measurements were made principally with two differential galvanometers, one controlling the two halves of the enclosed coil, and the other comparing one half with a platinoid fixed resistance. Readings were taken at the limiting points by bridge as check. Tubes not tapped in this series.

Temp. of oil bath at time of sealing 17.2°C.

No. of Obs.	Time	Temp. Hg.	Temp. from Bridge	Observed reading a.b.c.	Same with lead 0.3175 subtracted	Observed reading b.c.	Same for lead 0.3175	Observed reading a.b.	Same for lead 0.332	Balance reading added to 10.	Ratio log.	Calibration Reading	Temp. Hg. cal.
1	20.33	15.6°		10.230	9.9115	10.230	9.9125	20.11	19.788 = 19.824	17.	1.0067	12.128	15.6
2	.38					1.000						15.286	15.7
3	.40											17.212	15.8
4	.42											19.114	15.9
5	.45											21.278	16.0
6	.49											23.832	16.1
7	.52			1			1		1				
8	.54			0			0		0			26.826	16.2
9	21.00	16.4°		0			0		0			30.274	16.3
10	.07			5			5		5	10.	1.0044	33.654	16.4
11	.11				1.601							38.030	16.6
12	.19											41.602	16.8
13	.25											45.960	17.0
14	.30			16.23	15.911	16.16	15.842	32.01	31.688	15.	1.006	50.212	17.2
15	.31											49.264	17.4
16	.33											46.764	17.5
17	.36	17.8°										44.230	17.6
18	.41											43.054	17.8
19	.47											37.750	17.8
20												34.074	17.8
21				12.86	12.461	12.84	12.522	25.30	24.983	10.	1.0044	30.580	17.8
22					(1.255 mh)		(1.283 mh)		25.018 25.068 (1.262 mh)			29.758	17.8
												29.782	
												24.685	
												437.074	

No. of Obs.	Corrected Calibration Reading for lead	Coeff. r	(T-1)(Calib.)	Correction Factor	Corrected Normal abs. temp.	Corrected abs. temp. at Saturation	Temp. by air thermo.	Rise of temp. by air thermo.	Res. for balance	Res. in G. cal.	Ratio:	Ratio by bridge	Coeff. for 1° rise
1	0.000	1.0	0		290.2	290.2	17.2		7300	10,901.5	1.000		0.00809
2	3.158	3.150	1.04114	0.0005	290.4	302.4	27.4	10.2	6900 (a)	10,503	1.038 (a)		0.00373
3	5.182	5.170	1.08803	0.00078	290.5	310.3	37.3	20.1	6580 (a)	10,184.5	1.0704 (a)		0.00358
4	6.956	6.942	1.12167	0.001052	290.5	317.1	44.1	26.9	6300 (a)	9,906	1.1005 (a)		0.00373
5	9.150	9.136	1.1201	0.001381	290.6	325.5	52.5	35.3	5950 (a)	9,557.5	1.1406		0.00398
6	11.704	11.693	1.1536	0.001766	290.7	[illegible]	[illegible]	[illegible]	5650 (a)	9,259	1.1774		0.00393
7	14.498	14.488	1.1874	0.002218	290.9	347.0	73.7	56.5	5280 (a)	8,905	1.2261		0.00401
8	18.146	18.135	1.2261	0.002738	291.0	366.3	93.3	76.1	4900 (a)	8,513	1.2706		0.00386
9	21.326	21.320	1.2706	0.003217	291.2	372.7	99.7	82.5	4550 (a)	8,164.5	1.3352		0.00415
10	25.92	25.921	1.3349	0.003909	291.3	390.3	117.3	100.1	4100 (a)	7,716	1.4128		0.00424
11	29.474	29.475	1.3848	0.004448	291.5	404.3	131.3	114.1	3770 (a)	7,387.5	1.4757		0.00469
12	36.832	36.832	1.4333	0.005558	291.8	432.8	159.8	142.6	3220	6,839	1.5940	1.601	0.00416
13	38.284	38.285	1.4495	0.005747	291.9	437.8	164.8	147.6	3170	6,790.5	1.6054	1.601	0.00401
14	37.135	37.144	1.4374	0.005604	291.8	434.0	161.0	143.8	3250 (a)	6872	1.5863		0.00407
15	34.636	34.644	1.4545	0.005226	291.7	424.3	151.3	134.1	3400	7023.5	1.5521		0.00417
16	32.100	32.107	1.4345	0.004997	291.6	418.8	145.3	128.1	3620	7245	1.5047		0.00394
17	28.926	28.935	1.3796	0.004365	291.5	402.3	129.3	112.1	3900	7526.5	1.4484		0.00400
18	25.622	25.627	1.3363	0.003867	291.3	389.2	116.2	99.0	4200	7828	1.3926		0.00366
19	21.946	21.951	1.2880	0.003313	291.2	375.1	102.1	84.9	4550	8179.5	1.3328		0.00319
20	18.472	18.482	1.2419	0.002782	291.0	361.4	88.4	71.2	4930	8561	1.2734		0.00284
21	17.604	17.591	1.2314	0.002661	291.0	358.3	85.3	68.1	5010	8643	1.2613	1.261	0.00283
	37.07	37.07							5010				
		12000							105 30	17,649 1			
									169 22				
									174,492				



two inserted permanently on spool side of Act. Diff: Galv for balance in parallel. Both in series differential with both galvs.

Res: of Act: Diff: @ 19°C before heat.

After heat taken @ 20°C

7240	T.B. 19.5°
2	
7238 ÷ 2 = 3619	
7295	T.B. 20.0°C
2	
7293 ÷ 2 = 3646.5	

Res: of H.B. D.B. Diff before heat

5360	
2	
5358 ÷ 2 = 2679	

Capillary tube opened + recalibrated at 21.0 Temp: of oil bath by Nat. Std: Thermom: 17.8°C.

Bath by Nat. Std: Thermom: 17.8°C.

1 H.H.O cell working through 50ω + standard platinum res.

Barometer at time of heating

	75.52
Index error	.0344
	75.5644 @ 21.7°C
	.279
	75.285 @ 0°C

0.00017 × 21.7 = 0.003689
× 75.56 = 0.279

Barometer at calibrating readings 22.24 o'clock

	75.52
	.0344
	75.6244 @ 22.2
	.285
	75.339 @ 0°C

0.00017 × 22.2 = 0.00377
× 75.62 = 0.285

Same reading at close of heat.

Some slight p.d. when testing current was off, observed on diff. galvo. The zero was reset at nearly every observation and taken to the fixed it did not exceed 10 divs: and was supposed to be of thermoelectric origin.

Each div: of diff: galvo scale corresponds to about 0.7ω change of res:.

Full deflection on H.B. D.B = 250 ±. reading to 1ω.

Current strength in main circ: as usual about $\frac{0.75}{30 + 30 + \frac{50}{2}}$ = 7.5 bbb m-amp. Rate

Current strength in heating coil circ: 2 to 3 amperes.

No globule of mercury in right-angle tube.

0.0001623 × 17.2 = 0.002791
0.0001623 × 19.3 = 0.003132

3βt + H = 0.0115

The curve of results is added to the sheet on the preceding page.

Sept. 29. III. 90

Experiments on the Temp. Coeff. of Copper.

In this series the two differential galvanometers were again used under very favourable conditions, and the heat was considered a good one. The capillary tube was tapped before each observation, like a barometer to overcome friction.

No. of Obs.	Time	Temp. of Hg.	Temp. of Room & Bath	Obs. res. in ω	Corrected res. Index deducted ÷ 320	Obs. res. in ω	Corrected res. Index deducted ÷ 0.3195	Obs. res. in ω	Corrected res. Index deducted ÷ 0.3264	Rate of change	Balance Thermometer read. when added Hg	Ratio ÷ 10	Calibration Reading	Temp. of Hg. Nat. Std.
1	21.28	17.2	17.88 (int. 18.4°C out air 19°C)	10.230	9.910	10.225	9.8055	20.050	19.726 = 19.8155 + 0.0895		24ω	1.009	11.900	17.2
2	.40					Temp. of Bath 21.8°C.							13.684	17.2
3	.43					1.0008							15.890	17.2
4	.47	17.2								1.5246 ω			18.514	17.2
5	.52													
6	.55	17.5									15ω	1.006	21.366	17.3
7	22.00		19°C air 20.4 int.										24.318	17.4
8	.05									1.5425 ω	13ω	1.005	27.304	17.5
9	.10	17.6											30.200	17.6
10	.16	17.8											33.602	17.7
11	.24									1.548 ω	13ω	1.005	37.400	17.8
12	.34	18.8											40.638	18.3
13	.45			15.6400	15.320	15.600	15.280	30.850	30.526 ÷ 30.600		10ω	1.0038	43.754	18.8
14	23.02		20°C air int. 21°C.			1.002					8ω	1.003	45.492	19.0
15	.06													
16	.11	19.3											42.342	19.1
17	.15	19.3	19.2°C air										38.432	19.3
18	.17												34.956	19.3
													32.059	19.3
19	.19										20ω	1.0075	28.972	19.3
													26.0422	
													2342	
		326.722											326.722	

No. of Obs.	Rise of Calibration ÷ 10	Rise at 0°C.	θ-θ₀	(θ-θ₀)	(θ-θ₀)(θ+θ₀)	Correction Factor for Hg temp	Corrected Normal Atm. temp	Corrected Atm. temp at obs.	Temp. °C by Thermometer	Rise of °C by temp by thermometer	Res. for Balance	Res. in Galv. ωω	Ratio	θ-θ₀ for ωω	Res. of Galv. ωω
						1.002791	290.8	290.8	17.8	0	(-) 48.05 ω	5.64	1.0000		3619
1	0														
2	1.784	1.779	1.0236	0.00027	1.002791	290.9	297.69	289	7.1	1730 (-)	3349	1.0215	0.00303		3619
3	3.990	3.979	1.0528	0.000667	1.002791	291.0	306.14	334	15.6	1560 (-)	5180.5	1.0551	0.00353		3620.5
4	6.614	6.595	1.0876	0.000007	1.002791	291.1	316.6	436	25.8	1370 (-)	4992	1.0954	0.00369		3622
5	9.466	9.440	1.1254	0.001422	1.002891	291.2	327.7	547	36.9	1150 (-)	4773.5	1.1468	0.00396		3623.5
6	12.418	12.383	1.1837	0.002113	1.002824	291.4	344.9	719	54.1	970 (-)	4595	1.1991	0.00552		3625
7	15.404	15.360	1.2040	0.002268	1.002840	291.5	351.0	780	60.2	805 (-)	4431.5	1.2355	0.00310		3626.5
8	18.400	19.364	1.2435	0.002504	1.002856	291.6	362.6	896	71.8	600 (-)	4228	1.2955	0.00405		3628
9	21.702	21.640	1.2974	0.003305	1.002872	291.8	375.7	1027	84.9	435 (-)	4064.5	1.3482	0.00401		3629.5
10	25.000	25.427	1.3376	0.003882	1.002889	291.9	390.4	1174	99.6	250 (-)	3881	1.4120	0.00402		3631
11	28.738	29.652	1.3804	0.004371	1.002970	292.1	403.2	1302	112.4	105 (-)	3737.5	1.4674	0.00429		3632.5
12	31.854	31.757	1.4217	0.004850	1.003001	292.2	415.4	1424	124.6	-35 (-)	3669	1.5245	0.00420		3634
13	33.592	33.488	1.4447	0.005114	1.003093	292.3	422.3	1493	131.5	-97 (-)	3732.5	1.5501	0.00493		3635.5
14										-75	3712	1.5405			3637
15	30.442	30.348	1.4031	0.004635	1.003310	292.2	410.0	1370	119.2	+50 (-)	3688.5	1.4893	0.00405		3638.5
16	26.532	26.449	1.3512	0.004039	1.003132	292.0	394.55	1215	102.75	+230 (-)	3870	1.4209	0.00407		3640
17	22.056	22.984	1.3053	0.003511	1.003132	291.9	381.2	1082	90.4	400 (-)	4041.5	1.3604	0.00397		3641.5
18	20.158	20.095	1.2668	0.003046	1.003132	291.7	369.5	965	78.7	545	4188	1.3133	0.00381		3643
19	17.072	17.019	1.2260	0.002599	1.003132	291.6	357.5	845	66.7	715	4359.5	1.2622	0.00393		3644.5
	326.722						6817.64	1603.65	1252.25						
								44.14	320.4						
								6817.64	1603.61						

0.66238
0.67657
0.69487
0.72558
0.75409
0.78849
0.81834
0.85508
0.89241
0.93558
0.97119
1.00663
1.02668
1.02036
1.08646
0.94016
0.90103
0.86486
0.83594

The mitis ring was rewound and an error in the counting of its previous winding corrected.

The two rings tested were connected in series and the galvanometer connected with one or the other.

The throws with standard cell and condenser were taken three times with the following results — 1 Cleck cell 1 + 52.

No. of Series	EMF	Q abs.	No. of Throws	Mean Throw	Approx. Probable error E	Time of Obs.	Weight estimated	Mean	Value of 1 throw				
1	1.4431	1.4431×10^{-7}	11	181.5	±0.4	9.20	1	181.5	ob Q				
2	1.4431	1.4431×10^{-7}	8	182.3	±0.2	15.0	3	546.9	181.3	7.888×10^{-10}			
3	1.429	1.429×10^{-7}	9	178.1	±0.5	16.0	1	178.1					
								906.5					
								181.3					

$$\frac{7.888 \times 10^{-10}}{2 \times 335} \times 1000 = 1.1773 \times 10^{-12} \times 1000 = 1.1773 \times 10^{-9}$$

$$\therefore \frac{425}{5} \times d \times r \times 1.1773 \times 10^{-9} = \varphi$$

$$\frac{7.888 \times 10^{-10}}{2 \times 393} = 1.0027 \times 10^{-12}$$

Measurement of the Permeability of certain samples of iron cast at Schenectady and one of Mitis.

No.	Temperature by circling	A	B see page 22 facing	C	D	E	F	G	Mean EFG	Area of X section	Weight in air	Weight in water	Vol. by weight	Vol. by formula	Sp. g.
1	Mitis	18.2	16.05	16.05	1.12	1.123	1.12	1.125	1.122	1.019	4079	3529	55	54.8	7.4
2	Good cast	24.25		3.35 3.1	3.25	3.15	3.5	3.2	3.26	8.34-7	4001	2428.6	57.54	57.3	6.96

No.	Time on 1st Layer	Time on 2nd Layer	Time on 3rd Layer	Time on 4th Layer	Total time Running	Total time Standing	Total time Accumulated	Mean time of putting on					
1	335	328	274	231	1168	838	335	53.80	18.48				
2	393	193	174	–	750	357	393	69.28	5.152				

No. of Obs.	Time	Galvo.	Amperes	No. of Throws	Mean Throw	Approx. probable error	Res. of Galvo at	$\frac{G+S}{S}$	Res. of Galvo at Intrd.	φ	L	H	μ	Thousand Difflu.
1	10.22.	3'.45"		7	37.2	± 0.6	5250	1	5250	2.320×10^{-12}				
2	42	6'.5'		7	66.2	± 0.4	"	"	"	2.2580×10^{-12}				
3		13.15'		8	278	± 3.3	"	-	"	4.0092×10^{-12}				
4		16.30'		7	675	± 0.15	50,000	2.4025	26220	1.7196×10^{-12}	1.6862×10^{-12}			
5		22'.00'	Dry	5	1114.7	± 0.2	50,000	2.4025	26220	4.389×10^{-12}	4.209 "			162.1
6	11.33	31'.15" 0.093		6	100.5	± 0.6	100,000	3.105	33900	1.2465×10^{-12}	7.316 "			24.1.12
7		0.221		5	173	± 0.3	100,000	3.105	33900	2.144×10^{-12}	12.22			312
8	15.30	0.222		7	178	± 0.1	100,000	3.105	33900	2.08×10^{-12}				537.2
9		0.300		7	189	± 0.9	100,000	3.105	33900	2.342×10^{-12}				521.1
10		0.504		6	109	± 0.5	200,000	1	205,250	2.654 "				586.8
11		1.02		3	112	± 0.6	200,000	1	205,250	2.962 "				
12		2.005		4	112.5	± 2.6	200,000	1	205,250	3.441 "				

No. of Obs.	Time	Galvo.	Amperes	No. of Throws	Mean Throw	Probable error	Res. in Galvo at	$\frac{G+S}{S}$	Res. of Galvo at	φ	L	H	μ
1	10.22	3'.45.5'		7	28.8	±0.3	0	1	5250	1.52×10^{-12}			
2	10.42	6'.5'		7	50.6	± 0.5	0	1	5250	2.66			
3		13'.15'		8	119.6	± 0.5	0	1	"	4.392			
4		16'.30'		7	154	± 0.8	0	1	"	8.010			
5		22.00		6	220.2	± 0.9	0	1	"	1.360×10^{-12}			
6		0.093 31'.15"		7	62.9	± 0.5	0	1	"	4.091×10^{-12}			
7		0.221		7	114.54	± 0.8	50,000	1	55,250	9.456			
8		0.222		6	138.8	± 0.25	"	1	"				
9		0.300		7	128.3	± 0.5	"	1	"				
10		0.504		6	132	± 0.4	100,000	1	105,250				
11		1.02		4	105	± 1.7	200,000	1	205,250	2.161			
12		2.006		4	134.3	± 1.3	200,000	1	205,250	2.764			

25.2
15.5
9.6 × .00003 = .00288 = 1.00288

3750 ÷ 2 = 3725

3725 + 57 = 3782

$\frac{3782 \times 46.1058}{3725}$ = 46.8113 × 1/1 + 2.0 × 0.0038 = 1.0/1.0076 = 46.4580

$\frac{3725 + 45}{3725}$ × 46.1058 = 46.6627 × 1/1.0076 = 46.3107

26.4 − 19 = 7.4 × 0.03 = 0.222 × 0.467 = 0.1037

Final Determination of a Standard Resistance Coil of Copper for Bergmann & Co.

Both coils soldered and enclosed. Insulation o.k. Standing in water side by side at temp. of 23.1° C by our thermometer #1.

Bridge at 25.2° C., and 46 ω in this = 45.9734 Equal ω standard @ 25.2
= 45.9734 × 1.00288 = 46.1058 ω at temp.

#1 coil 57 ω added to its side. = 46.8113 @ 23.1° C. = 46.4580 ω @ 21.1° C

#2 coil 45 ω - - - - = 46.6627 @ 23.1° C = 46.311 ω @ 21.1° C.

By Bridge

# 1	46.795 − 0.088	= 46.707	@ 26.4° C T.B	= 46.8107 ω	@ 23.1 = 46.4576
# 2	46.550 − 0.088	= 46.462	@ 26.4° C.	= 46.5657 ω	@ 23.1 = 46.2104

Some accident has apparently happened to #2.

On the conductors required to give Incandescent light to Mr Ewell's house.

The feeder to the catch box has a res. of 0.128 ω on each side and those to Archibalds' 0.104 ω making a total of 0.232 ω on each outside conductor.

As the load in winter is usually 80 amperes on each side there must be 10 volts drop at the catch box, and perhaps 12.5 volts drop in all to the house.

If there are 50 lights on Mr Ewell's house at full load = 11 amperes at full load, the drop being say 9 volts = 0.82 ω and for 4000 feet = 0.000205 ω per ft. #6 wire has actually 0.00025 ω and 4000 feet = 8.0 ω ∴ 11 volts drop at full load. This wire is 0.125 lbs per foot × 12000 feet = 1500 lbs. @ 0.30 = $450

80 main at usual price of $0.752 per foot would cost about $3000.

Calibration of Thermometers used as Standards.

On the 3rd Apr. 1890. Observations were taken with three normal thermometers having their bulbs and stems up to zero in washed and broken melting ice.

Chemical Room Standard indicated	−0.4° C.
Our standard #1	+ 0.2
- - #2	+ 0.2

On the 10th Apr. Observations in an apparatus for generating free steam showed :-

Chemical Room Standard	+ 99.35
Our Standard #1 (in steam 440°)	+ 99.0
- - #2 (- - - 50°)	+ 99.2

Barometer at time 75.250
@ 86° F

75.250	
− .046	vibr
75.204	@ 20° C
− .384	
74.810	reduced pressure.

600° F showed 205° F

= 99.6° 0 boiling temp.

Correction to Chemical room standard	+ 0.25
- - Our Standard #1	+ 0.6
- - - - #2	+ 0.4

Table of corrections for our Std #1 is given in Book 1 page 137.

The capillary mercury column was tapped with the finger before all observations in this book.

Res: of Astatic Diff. galv. adj differentially to be permanently mounted on afool side to balance in multiple arc.

7311 = both coils
2 leads
7309 ÷ 2 = 3654.5 ω each coil. Before heat. T.B. 20.8°C

7329 = both coil after heat T.B. 21.8°C
of 1°C temp. extn.
7338
2 leads
7336 ÷ 2 = 3668 ω each coil.

1 div: of scale represents change of about 1ω in balancing resistance.

Res: of H.R.D.S. Diff. galv: adj: differentially to balance in multiple arc.

5421 both coils T.B. 20.8°C
2 leads
5419 ÷ 2 = 2709.5 ω each coil

1 div: of scale represents change of about 3ω in balancing resistance.

Temp: of Oil bath at time of reading capillary tube (after opening same) (292.75K) 19.75°C by #1 standard thermometer. No hysteresis of mercury in effect.

Barometer reading at time of test 76.140
.044 Index error
76.184 @ 23.3°C.

23.3 × 0.00017 = 0.03961
× 76.184 =
.302
75.882 @ 0°C

reading at culminating observation 76.210
.044
24.3 × 0.00017 = 0.0413
× 76.254 =
76.254 @ 24.3
0.375
75.939 @ 0°C.

Corrections same as those facing page 24. 1 KHO cell working through 50ω platinoid standard res: of about 1ω.
Astatic Diff. galv. comparing platinoid res: with coil in air thermometer.
Dead beat " " copper bell coils.
Bridge checking: 0.01ω represented by 3 div. ie KHO cells working.

3pt + K = 0.0115 see preceding cases.

No. of Obs.	Coeff. for Temp.	N	√N	Wt	Wt/N	Wt/N Coeff	General Mean	r	r.m	r²	r³	r⁴
2	0.4037	10	3.16	3	9.48	3.2280		0.0022	4.34 × 10⁻⁴	48.89 × 10⁻⁶	0.1096 × 10⁻⁶	0.0126
3	0.3883	22.4	4.73	3	14.19	5.509		0.0147	7.29	2.55		÷ √5.09
4	0.3902	31.1	5.54	3	16.62	6.533		0.0148	21.46	—	0.159 × 7.99 × 10⁻⁶	= ÷ 23.4
5	0.4076	47.2	6.87	2	13.74	5.600		0.0037	2.96	39.71	= 1.26 × 10⁻⁶	= 126 × 10⁻⁶ / 23.4
6	0.4066	60.0	7.75	3	15.50	6.302		0.0087	0.40	7.54		
7	0.4085	73.1	8.55	4	17.10	6.985		0.0026	2.76	115.60	0.0126	= 5.42 × 10⁻⁶
8	0.4063	84.9	9.21	3	27.63	11.230		0.0004	0.16	4.42		
9	0.4055	95.2	9.91	4	38.64	16.075		0.0004	.16	6.34		
10	0.4062	111.6	10.56	4	42.24	17.160	0.40594	0.0060	0.09	0.54		
11	0.4058	123.2	11.10	1	11.10	4.504		0.0001	.01	0.11		
12	0.4081	135.2	11.63	3	34.89	14.240		0.0022	4.84	168.80		
13	0.4057	148.5	12.20	4	48.80	19.950		0.0028	7.84	382.70		
14	0.4110	161.9	12.72	4	50.88	20.915		0.0061	24.01	1323.00		
15	0.4094	176.2	13.28	5	66.40	27.120		0.0025	6.25	415.10		
16	0.4062	189.2	13.21	3	39.63	14.850		0.0023	0.09	3.30		
17	0.3999	115.5	10.75	4	42.00	16.795		0.0060	36.00	1512.00		
18	0.3995	103.8	10.19	2	20.38	8.141		0.0064	40.96	834.80		
19	0.4010	88.2	9.39	4	37.56	15.060		0.0049	24.01	961.80		
20	0.4017	72.2	8.50	4	34.00	13.660		0.0042	17.64	594.79		
2					579.66	236.790		0.0425	266.67	9364.66		
					3.51	3.15		0.0022				
					31.71	12.345						
					547.97	222.445						

Experiments on the Temperature Coefficient of Copper.

Sunday 30.II.90
This series was practically a repetition of that recorded on page 24, with the addition however of a somewhat higher limiting temperature.

No. of Obs.	Time	Temp. of Room Bridge	Obsd. res. of a ch.	Same with lead deducted 0.350	Obsd. res. of box.	Same with lead deducted 0.321	Obsd. res. of a ch. 0.2.24	Same with lead deducted 0.2.24	Ratio of Change	Barometer Index. Pressure in In.	Barometer Reading	Ratio of Temp.	Temp. of by Coil
1	20.40	20.5	21.7	10.300	9.930	10.290	9.969	20.190	19.866 / 2.79 gms 0.023		20.0	1.0072	11.918
2	.43												14.288
3	.46												17.672
4	.50												20.690
5	.54												24.060
6	21.05	20.6	21.9								10.0	1.0074	27.212
7	.08												30.644
8	.15												33.662
9	.21	21.9											37.044
10	.23												40.042
11	.33										8.0	1.0093	43.644
12	.37												46.492
13	.42	20.6											49.922
14	.46												53.270
15	.55												56.930
16	22.05		22.1					34.520	34.896	1.7211	8.0	1.0093	59.020
17	.09												41.222
18	.17	20.9									11.0	1.0055	38.460
19	.22												34.468
20	.30	20.5	22.2										30.374
21													12.752

No. of Obs.	Coeff. for Temp.	Corrected mean of Temp. 0°C	Coeff.	1/(1+αθ)	Corrected Normal abs. temp	Corrected abs. temp at obs.	Temp. of by mean thermometer	Ratio of T by mean thermometer	Ratio adopted for balance	Ratio in Galvo. calc.	Ratio in Galvo. coil	Ratio	Ratio of resistance	Coeff. per °C. mean
1	1.0002986				292.75	292.5	19.8		1.017	5866.5	3654.5	0.6229		
2	1.0002986	0.0023 / 5.562	1.0338	0.000289	292.86	302.8	29.8	10.0	1600 (1)	5255	3655	0.69552	1.0407	0.4037
3	1.0002986	0.0023 / 5.737	1.07568	1.000570	293.00	315.2	42.2	22.4	1375 (1)	5030	3655	0.72664	1.0584	0.3883
4	1.0003003	0.0023 / 6.746	1.11537	1.001337	293.13	326.9	53.9	34.1	1170 (1)	4825	3655	0.75751	1.13097	0.3902
5	1.0003019	0.0023 / 12.085	1.15941	1.001833	293.28	346.0	67.0	47.2	930 (1)	4585	3655	0.79715	1.19247	0.4076
6	1.0003035	0.0023 / 15.347	1.20243	1.002216	293.43	352.8	79.8	60.0	740 (1)	4395	3655	0.83163	1.24396	0.4066
7	1.0003051	0.0023 / 18.466	1.24526	1.002523	293.58	365.9	92.9	73.1	555 (1)	4210	3655	0.86817	1.29862	0.4085
8	1.0003067	0.0023 / 21.898	1.28935	1.002788	293.71	377.7	104.7	84.9	410 (1)	4066	3656	0.89915	1.34449	0.4063
9	1.0003084	0.0023 / 25.084	1.33044	1.003000	293.86	391.0	118.0	98.2	255 (1)	3912	3657	0.93481	1.39831	0.4055
10	1.0003100	0.0023 / 28.157	1.37562	1.003220	294.00	404.4	131.4	111.6	107 (1)	3765	3658	0.97158	1.45331	0.4062
11	1.0003132	0.0023 / 31.347	1.41415	1.003462	294.114	416.0	143.0	123.2	-10 (1)	3669	3659	1.00273	1.14999	0.4058
12	1.0003165	0.0023 / 34.485	1.45461	1.003723	294.27	428.0	155.0	135.2	-137 (1)	3797	3660	1.03743	1.55181	0.4081
13	1.0003218	0.0023 / 37.891	1.49964	1.003767	294.43	441.6	168.6	148.8	-275 (1)	3936	3661	1.07512	1.60818	0.4057
14	1.0003242	0.0023 / 41.318	1.54470	1.004322	294.58	454.7	181.7	161.9	-415 (1)	4077	3662	1.11333	1.66533	0.4110
15	1.0003317	0.0023 / 44.883	1.59178	1.004605	294.74	469.2	196.2	176.4	-550 (1)	4213	3663	1.15015	1.72046	0.4094
16	1.0003317	0.0023 / 47.971	1.63105	1.005762	294.844	484.0	169.0	149.2	-270 (1)	3931	3664	1.07369	1.60605	0.4062
17	1.0003317	0.0023 / 24.493	1.28818	1.004644	294.11	401.3	135.3	115.5	+ 85 (1)	3780	3665	0.97733	1.46191	0.3999
18	1.0003317	0.0023 / 26.436	1.34939	1.004217	293.93	396.6	123.6	103.8	210 (1)	3876	3666	0.94582	1.41477	0.3995
19	1.0003317	0.0023 / 30.445	1.42710	1.003416	293.75	381.0	108.0	88.2	385 (1)	4052	3667	0.90498	1.35368	0.4010
20	1.0003317	0.0023 / 34.35	1.24616	1.002796	293.57	365.0	92.0	72.2	585 (1)	4258	3668	0.86245	1.29006	0.4017
						767.1	221.1	188.9						
							546.0	396.0						
							767.1	221.1						

Red figures consist of correction of Barometer.

Deposits

	Before	After	Loss
Weight of matte	19275	18190	1085
Weight of anode copper plate	1115	479	636
Weight - cathode -	331	936	-605

The quantity of copper dissolved by 1 amp. sec = 0·03279 gms
" " " hr = 1·181 "

$$636 \div 1.181 = 538.5 \text{ amp. hrs.}$$

$$1085 \div 538.5 = 2.015 \text{ gms. per amp. hr.}$$
$$= 2{,}162 \text{ amp. hrs. per lb.}$$

640,000 amp hrs. dissolve 1 lbs (200000) of matte.
640,000 ¢ watt - - - - - - - - - at counter cost ¢
640¢ ribbon - - - - -
640¢ × 0·776 c - - - - -
= 4·97 ¢ $

The res. of the bath is 0·22ω = 0·15ω per sq. ft
120 d. kwt: hrs mechanical power needed per hr
93·1 d c.
0·93 d $ per hr.

At 24 hours a day the number of sq. feet of matte per hr daily
$= \frac{26{,}600}{d}$

Experiments on Electro-deposition of Matte.

The same large earthenware bath was used as in the experiment recorded on page 20, but the porous division was replaced by a towel fabric of asbestos supported by soft rubber matting, on each side. The matte plate was 10.7" (27.18) × 10.7" (27.18) × 2.25" (5.715). Its total volume was thus 4,232,230 ... + its weight was 6143 g (18230). Its sp. gr. was therefore 2.316

The salt water employed was a filtered solution of density 1.16 @ 18° C. The matte plate was immersed to a depth of 9.4" (38.2) and the surface exposed on one face to the liquid would thus be 9.4 × 10.7 = 100.6 sq. in: (649 □") = 0.7 sq. foot.

A large copper voltameter was joined up in circuit with the bath. The plates were 10.5" (42.6) × 8.25" (33.5) (immersed) in aqueous solution of $CuSO_4$. thus exposing 1427 sq. cms on one face. Density of solution 1.040 at 18° C.

By a series of measurements similar to those on page 20 the counter e.m.f. of polarisation at starting was 1.30 volts and the resistance 0.22 ω; or a res: of 0.15ω per sq. foot. The resistance of the fluid per sq. foot was found as follows:— Two matte plates each exposing (approximately) 1 sq. ft on each face immersed in bath parallel.

Res: of leads 0.03 ω.			bare lead
- between plates separated by	0.5" (1.26)	0.07ω	= 0.04
- - - - -	1" (2.5)	"	"
- - - - -	2" (5.0)	0.08ω	0.05
- - - - -	2.5" (6.3)	0.09	0.06

2" distance increased res. by 0.02ω or about 0.01ω per inch of distance. The res. per sq. foot will therefore be (0.04 + 0.01 s)ω where s is the distance apart in inches. The distance between the matte and carbon is 4", and the res: should be 0.08 = 0.11 + the res: of the carbon plate which should be negligible. The res: of the porous diaphragm is thus 0.11ω or 0.08ω per sq. foot.

The following results were obtained after the test had been running for over 24 hours and are therefore probably reliable.

No. of Obs.	Before scraping: Bloch	Current	P.D.	Counter emf	P.D. corr. bath (P.D.−c.e.m.f.)	$ per hr TENT	$ per hr	After scraping: Bloch	Current	P.D.	Counter emf	P.D. corr. bath	$ per hr Comp.	$ per hr Comp.
1	1·82	9·19	3·7	1·68	2·02	1·7 volts	12·10	1·86	9·39	3·6	2·07	1·53	1·57 volts	12·11
2	1·66	8·38	3·55	1·71	1·84		11·16	1·60	8·05	3·35	1·78	1·57		11·16
3	1·48	7·47	3·40	1·76	1·64	$9·50	9·80	1·38	6·97	3·10	1·88	1·57	$7·85	9·67
4	1·24	6·26	3·1	1·72	1·38		8·37	1·13	5·67	2·80	1·25	1·55		8·10
5	0·95	4·80	2·8	1·74	1·06		6·51	0·795	4·00	2·45	0·88	1·57		5·93
6	0·64	3·23	2·4	1·69	0·71		4·38	0·444	2·22	2·0	0·49	1·51		3·29
7	0·44	2·22	2·15	1·66	0·49		2·98							
8	0·235	1·18	1·85	1·59	0·26		1·58							
9	0·140	0·71	1·72	1·56	0·16		0·93							

Permeability of certain samples of Ferro-aluminium Castings from Schenectady

Small anchor ring of Mitis iron

A	B	C	D	E	F	G	Mean DEFG	Mean area of X section	Weight in air	Weight in water	Volume by weight	Volume by form	Sp. g.
18.2	16.05	16.05	1.121	1.123	1.12	1.125	1.122	1.019	407.9	352.9	55	54.8	7.4
	Turns on 1st layer	Turns on 2nd layer	Turns on 3rd layer	Turns on 4th layer	Total turns.	Total primary turns	Total secondary turns	Mean circumf. of ring	Turns of primary per cm.	1.257 × Turns of primary per cm.			
	335	328	274	231	1168	505	663	53.80	9.39	11.81			
	Time	Source of E.M.F.	Bonds.	EMF at temp.	a × 10⁷	No. of throws	Mean throw	τ (throw)	Value of 1 div.	Mean value of 1 div.	a 2πk/63		
	15.00	2 Cells 22C	0.408†	2.860	1.167	13	103.15	± 0.2	8.838 / 1.399×10⁻⁴	1.11×10⁻⁴ / 8.80			
	17.00	2 . . 23C	0.408†	2.858	1.166	5	102.5	± 0.1	8.790 / 2.0975	8.370×10⁻⁴	1.261		
No. of Obs.	Time	Galvo Defln	Amperes	No. of throws	Mean Throw	τ (throw)	Res. in cct. with Galvo	Total res. in Galvo cct.	a 7526	φ	B	μ	H
1	14.02	6.10′	0.0814	5	49.2	± 0.6	0	52.50	3.266×10⁻⁴	1.714×10⁻⁴	168	175	4.96
2	14.15	6.50′	0.0903	5	54.2	± 0.4	0	-	3.598	1.889	185.4	173.8	1.047
3	·20	8.0	0.1059	5	67.9	± 0.9	0	-	4.507	2.366	224.3	183.3	1.251
4	·36	9.0	0.1194	6	82.4	± 0.6	0	-	5.470	2.871	281.8	199.5	1.410
5	·45	12.05′	0.1614	6	190.1	± 1.3	0	-	12.62	6.626	658.3	314.2	2.096
6	·51	14.45′	0.1985	7	147.9	± 0.5	25000	25250	3.179	1.688	914.0	402.8	2.268
7	15.00	22.0′	0.3047	7	141.8	± 1.0	"	-	9.41	2.847	2794.0	7764	3.598
8	·10	{55.30′ / 8.222}	{1.097 / 1.131}	5	111.3	± 0.2	100000	105250	7.388	3.776	8613.	657.6	13.10
9	·21	0.398	2.010	5	136.9	± 0.05	"	"	9.087	3.544	9386.	395.2	23.75
10	..	0.698	3.526	7	78.4	± 0.3	200,000	205,250	5.204	1.068	10,480	251.7	41.64
11		1.050	5.456	7	83.4	± 0.1	-	-	5.536	1.136	11,150	162.2	68.33
12		1.520	7.678	6	88.0	± 0.25	-	-	5.841	1.199	11,770	123.2	90.67
13		2.914	14.350	5	95.5	± 0.1	-	-	6.339	1.301	12,770	75.37	169.4
No. of Obs.	Galvo Defln	Tam.	Amperes for tam 1.	Res. in cct of tam	Total res. corrected		Corrected φ	Corrected B	corrected μ	H	ρ		
1	6.10′	0.1080	0.754	4l + 110ω	1300ω		216.	212	221	0.96	4525		
2	6.50′	0.1198		4l —			238	234	219	1.067	4.566		
3	8.0′	0.1405		3l + 110ω			299	289	231	1.251	[illegible]		
4	9.0	0.1584		3l —			362	335	252	1.410	3.[illegible]		
5	12.05	0.2141		2l + 110ω			836	820	420	1.996	2.316		
6	14.45′	0.2633		2l —			1213	1190	508	2.344	1.969		
7	22.0′	0.4040		1l + 110ω			3591	3524	979	3.598	1.021		
8	55.30′	0.4550		110ω			10890	10560	829	13.10	1.206		
							12060	11840	498	23.75	2.004		
							13470	13220	317	41.64	3.155		
							14320	14070	205	68.43	4.678		
							15120	14850	155	90.67	6.452		
							16140	16110	95	169.4	8.53		

On the Permeability of Mitis Iron from Schenectady
Correction of observations taken on page 22.

A	B	C	D	E	F	G	Mean DEFG	Wt in air	Wt in water	Vol. by B.&S.	Vol. by formula	Sp. G.
18.2	16.05	16.05	1.12	1.123	1.12	1.125	1.122	407	352	55	56.53	7.44
	No. of turns in 1st layer	Turns in 2nd layer	Turns in 3rd layer	Turns in 4th layer	Total for turns	Total sec turns	Mean circumference	Mean turns per foot	Area of x section	1.257 × A × turns per foot		
	335	234	250	234	4824	569	53.80	8.995	1.019	9.166		
	EMF	Log.	$a \times 10^7$	No. of Obs.	Mean Turns	σ (Turns)	Mean per div.	Mean a per div.	$\frac{a}{1838}$			
	1.431	1.000	1.431	6 10	173.7 176.5	± 0.16 ± 0.6		8.166×10^{-10}	7.175×10^{-10}			
No. of Obs.	Time	Galv. Defl.	Amperes	No. of Turns	Mean Turns	σ dim	Res. of Galv. ck	$\frac{G \times S}{(S+G) \times 1000}$	Influence Turns	$\frac{a}{1838}$	φ	
1	14.15	14.07	0.190	5	29.7	± 0.7	30,200	5.21	154.7	1.110×10^{-10}	2.242×10^{4}	
2	.27	{26.15 8.061}	{0.372 0.105}	7	57.0	± 0.6	-	-	297	2.131	4.304	
3	.55	0.120	0.606	6	77.0	± 0.4	-	-	401.	2.878	5.813	
4	15.09	0.214	1.080	4	92.5	± 0.25	-	-	482	3.459	6.986	
5	.17	0.302	1.526	7	44.1	± 0.5	45,200	-	229.8	1.649	7.454	
6	.30	0.510	2.576	6	48.8	± 0.5	-	-	254.3	1.825	8.248	
7	.38	0.760	3.84	4	51.1	± 0.4	-	-	266.3	1.911	8.638	
8	.45	1.025	5.178	2	55.0	± 1.6	-	-	286.6	2.056	9.292	
9	.45			3	120.0	± 2.6	24,200	-	625.2	4.487	9.886	
10	.48	1.615	8.16	2	128.5	± 1.2	-	-	669.5	4.805	9.704	
11	.56	2.390	12.07	2	135.0	± 1.7	-	-	703.4	5.048	10.200	
12	16.00	0.210	1.061	3	92.7	± 0.5	-	-	483.0	3.466	7.000	
No. of Obs.	$\varphi \times 10^3$	$\frac{\varphi}{\mu} \times 10^3$	6H	Amp	H	μ						
1	2.242	2.200	10.43	0.190	1.74	1265	0.7905					
2	4.304	4.225	18.427	0.340	3.116	1356	0.7375					
3	5.813	5.706	33.22	0.606	5.554	1027	0.9737					
4	6.986	6.858	59.21	1.080	9.898	693	1.443					
5	7.454	7.317	83.66	1.526	13.99	523	1.912					
6	8.248	8.096	141.2	2.576	23.61	343	2.915					
7	8.638	8.478	210.5	3.840	35.20	241	4.149					
8	9.292	9.122	283.9	5.178	47.46	192	5.209					
9	9.886	8.898				187.5	7.85					
10	9.704	9.526	447.4	8.160	74.80	127.3	7.85					
11	10.200	10.010	661.8	12.07	110.6	91.3	10.9					
12	7.000	6.870	58.17	1.061	9.72	707						

Permeability of samples of cast iron from Schneider & Co.

All primaries in series and secondaries connected in turns to galvo.

No. of Ring	A	B	C	D	E	F	G	Means DEFG	Wt. in air.	Wt. in water	Vol. by H_2O	Vol. by form	Sp. gr.
1	25.39	19.05	19.05	3.15	3.2	3.15	3.25	3.19	3983?	3459	524?	556	7.16
2	25.45	18.93		3.25	3.15	3.5	3.20	3.26	4004	3428.6	575.4	581.8	6.96
3	25.10	18.95	3.3 3.3	3.1	3.2 3.25	3.15	3.25 3.05	3.20	3877	3336	541	556.3	6.97
4	25.10	19.0	19.0	3.2 3.1	3.2	3.15	3.2	3.17	3884	3331	553	546.8	7.13
5	25.20	18.8	18.95	3.25 3.15	3.1	3.25	3.25	3.20	4025.5?	3402	623.5?	558.7	7.23

No. of turns 1st layer	Turns on 2nd layer	Turns on 3rd layer	Total turns	Total primary turns	Total Sec. turns	Mean diam.	Primary turns per cm.	Area of X Section	1.257 X pr. turns per cm.	No. of rings	Bamboo insul. by coating % at.	Bamboo insul. % of Wt. by weight
383	166	163	712	329	383	69.660	4.722	7.98	5.936	1	Ord. Bamboo	0.06%
393	183	174	750	357	393	69.705	5.121	8.347	6.436	2	" "	0.06%
386	175	158	719	333	386	69.200	4.812	8.040	6.048	3	1:38	0.06%
381	175	161	717	336	381	69.280	4.850	7.892	6.096	4	1:38	0.06%
380	183	163	726	346	380	69.230	4.998	8.040	6.281	5	~~1:38~~	~~0.07%~~

No. of turns	Source of EMF	Resist.	EMF at temp	a	No. of Rings	Mean Rad.	σ_m (calc)	Mean a per cm	a / 2πr			
1	2 dech. cells @ 21°C	0.409 Ω	2.663×10^{-8}	1.171×10^{-7}	7	103.3	± 0.1	1.134×10^{-8}	1.48×10^{-10}			
2		$\times 10^{-3}$						~~1.443~~	1.443			
3									1.469			
4									1.489			
5									1.492			

No. of turns	Resist. of primary	Resist. of secondary.	Insulation between pr. & sec. by bamboo.
1	0.145 Ω	0.61 Ω	∞
2	0.155 Ω	0.63 Ω	∞
3	0.145 Ω	0.62 Ω	∞
4	0.150 Ω	0.60 Ω	∞
5	0.155 Ω	0.615 Ω	∞

Permeability Measurements of five samples of iron from Schemeldody

No. of Obs.	Force	Galvo Defl.	Time	[illegible]	D 3.28 No. of Hours	Mean Hour	r dist.	Rev. in est. coil. g	Rev. of G. est.	1.48 φ	L	H	μ	3/05 No. of Hours	Mean Hour	r dist.	1.483 φ	L	H	μ
1	8·53	6·40'	0·11699	0·0881	6	26·3	±0·25	0	5250	2.043×10^{10}	256	0·523	49	6	43·2	± 0·1	3.27×10^{10}	39·2	0·567	69
2	9·16	13·50'	0·24424	0·1857	6	58·2	± 0·24	0	"	4·522	56·7	1·103	51	6	94·8	± 0·7	7·184 "	86·1	1·195	72
3	9·50	25·15'	0·53732	0·4051	6	71·0	±0·8	50000	10250	1.077×10^{10}	135	2·405	56·1	7	122·4	± 0·3	1.810×10^{10}	217	2·608	83
4	10·18	54·30'	1·4019 0·222	1·057 1·121	6	150·7	± 0·8	25000	30,250	6·746	846	6·375 6·652	135 127	6	170·2	± 0·5	7·428	890	6·902 7·214	131 123
5	10·37		0·409	2·066	6	143·4	± 0·4	100,000	105,250	2.233×10^{10}	2800	12·27	228	6	153·2	± 0·6	2.325×10^{10}	2790	13·3	210
6	11·00		0·713	3·612	7	120·1	± 0·2	200,000	205,250	3·649	4570	21·45	213	7	127·2	± 0·9	3·766	4510	23·25	194
7	11·19		1·000	5·05	6	97·5	± 0·1	300,000	305,250	4·406	5520	29·98	184	6	103·2	± 0·2	4·546	5450	32·51	168
8	11·37		2·084	10·12	6	131·2	± 0·4	300,000	"	5·927	7430	60·07	124	6	137·3	± 0·2	6·049	7250	65·114	111
9	11·40		2·000	20·21	2	166·3	± 0·3	300,000	-	7·512	9414	120·0	78·5	2	171·5	± 0·8	7·554	9050	130·1	69·6

No. of Obs.	D 3.28 No. of Hours	Mean Hour	r	H	1.483 φ	L	μ	D 3.28 No. of Hours	Mean Hour	r	1.483 φ	L	H	μ	3/05 No. of Hours	Mean Hour	1.483 φ	L	H	μ
1	6	43·3	±0·2	0·53	3.348×10^{10}	41·6	78·	6	43·3	±0·1	3.38×10^{10}	42·8	0·537	79·7	6	37·5±0·2	2.94×10^{10}	36·6	0·55	66·5
2	6	95·1	±0·2	1·123	7·336	91·2	81·	6	95·0	± 0·2	7·425	94·1	1·132	83	6	82·5±3	6·49	80·7	0·66	69·2
3	6	122·6	± 0·3	2·45	1.886×10^{10}	230·	94·	6	121·7	± 0·2	1.857×10^{10}	235·3	2·47	95·	6	105·3 ±0·6	1.611×10^{10}	200·4	2·54	78·8
4	6	169·3	± 0·4	6·39 7·8	7·524	936	147 138	6	171·6	± 0·2	7·716	978	6·44 ·83	152 143	6	135·7 ±0·2	6·128	762	6·636 7·040	115 108
5	7	147·7	± 0·1	12·5	2.283×10^{10}	2840	227	6	147·2	± 0·1	2.307×10^{10}	2920	12·6	232	6	132·6±0·2	2·083	2590	12·97	200
6	7	122·7	± 0·1	21·85	3699	4600	211	7	121·6	± 0·2	3·716	4710	22·02	214	7	114·7 ± 0·1	3·513	4370	22·69	193
7	6	99·3	± 0·2	30·55	4·454	5540	181	6	98·3	± 0·1	4·469	5660	30·79	184	6	93·5 ± 0·2	4·273	5315	31·72	168
8	6	131·5	± 0·3	61·2	5·896	7334	120	6	130·2	± 0·8	5·918	7500	61·68	122	6	127·8 ± 0·1	5·821	7241	63·55	114
9	2	163·0	± 0·0	122·2	7·310	9090	74·	2	162·25	± 0·1	7·374	9345	123·2	76	2	160·5±0·4	7·310	9092	127·0	[illegible]

A sample of this rayligist iron wire (0.020") was weighed as follows:

in air	10·475 g.
" water	8·700
loss.	1·775

sp. g. 5·90

Another sample of the same wire very slightly roughed

in air	10·700
" water	9·270
	1·430

sp. g. 7·12.

In the cylindrical form the density might be

$0.7854 \times 5.9 = 3.927$

as a limit perhaps 4·0 under pressure

This coil had a sp. g. of about 3·37 so that, the space actually occupied by wire was $\frac{3.37}{5.9}$ of the total space.

On scraping off the oxide from the wire the diameter of the latter was found to be reduced to 0·18 or in ratio $\frac{324}{400}$, 0·81

Finally, the space occupied by iron would only be 0·7854 of the space occupied by compressed wire, so that the iron in the cross-section of this wire only occupied

$\frac{3.37}{5.9} \times 0.81 \times 0.7854 = 0.3635$ total space. $= \frac{1}{2.75}$

Permeability of Sample Castings of Iron from Schneckady, and our Rayligist wire.

Description	A	B	C	D	E	F	G	Mean DEFG	Wt in air	Wt in water	Wt by H_2O	Wt by Form	Sp. g.
Wire (rayligist)	23·57 23·3 23·1	18·4 (22·2) 17·5 (18·9) 17·97	2·55	2·75	2·6	2·7	2·75	2·69	1247	-	-	370	3·37
Metis	18·2	16·05	16·05	1·12	1·123	1·12	1·125	1·122	409·9	352·9	55	54·8	7·4

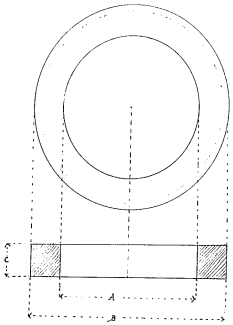
Description	Turns 1st layer	Turns 2nd layer	Turns 3rd layer	Turns 4th layer	Total turns	Total Arr. turns	Total Section	Mean diac.	Turns of per cm	1·267 × Turns per cm	Mean area of X section	Res. of Arr.	Res. of Sec.
Wire	379	170	162	–	701	332	379	65·08	5·10	7·1444	5·683	0·11 ω	0·51 ω
Metis	335	328	322	303	1288	953	335	53·8	17·71	22·26	1·019	0·89 ω	0·22 ω

Description	Source of EMF	Temp	EMF @ temp	Coeff. ρ	a ×10⁻⁷	No. of turns	Mean turns	t (Wire) (Metis)	a per div.	a (Wire) (Metis)	
Wire	2 Ba.	20°C.	2·865	0·410	1·175	6	103	±0·1	×10⁻⁹ 1·1425	1·505×10⁻⁷ 1·702×10⁻⁷	
Metis											

No. of Obs.	Time	Galvo.	Tangent	Ampère	No. of turns	Mean turns	t (Wire) (Metis)	Res. of G. ckt.	φ	Z	H	μ	1·505×10⁻⁷ × 4π×10⁻⁷
1	9·06	6°40'	0·1169	0·081	6	23·1	±0·2	5250	192·5	32·014	0·579	55·3	7·90
2	·33	12°	0·2126	0·160	6	45·8	± 0·3	"	361·8	63·67	1·143	55·7	
3	·45	22°	0·4040	0·3047	7	110·2	± 0·8	"	870·4	153·2	2·177	121·3	
4	·57	55°30' 0·217	1·4550	(1·097 / 1·096)	6	127·1	± 1·0	105,250	16670	2938	7·834	37·43	1·5834×10⁻⁷
5	10·12	0·435		2·97	6	170·6	± 0·9	"	27020	4754	15·70	30·38	
6	·29	0·700		3·536	6	96·5	± 0·5	205,250	29810	5245	25·27	20·76	3·089 × 10⁻⁷
7	·40	1·080		5·455	7	108·1	± 1·1	"	33400	5877	38·97	15·68	
8	·.	1·92		9·790	6	114·4	± 0·5	"	35326	6219	69·32	8·97	
9		4·65		23·500	7	120·9	± 0·9	"	37350	6572	167·9	39·13	

No. of Obs.	Ampère	No. of turns	Mean turns	t (Wire) (Metis)	Res. of G. ckt.	φ	Z	H	μ	1·702×10⁻⁷ × 4π×10⁻⁷	ρ	Z for unit × 2·75	
1		6	99·8	±0·4	5250	892	8·756	1·803	485·7	8·936	0·2057	88·	
2		6	79·4	± 0·5	30,250	7090	4020	3·561	1129	51·490	0·4557	175	
3		6	143·3	± 0·3	30,250	7350	7244	6·781	1088	51,490	0·9191	421·1	
4		6	69·7	± 0·2	105,250	12490	12,260	21·42	511	179·15	1·957	5066	
5		6	79·7	± 0·8	"	14,280	14,020	48·90	292	"	3·426	13060	
6		6	85·5	± 0·3	"	15,320	15,040	78·70	195	"	5·128	14420	
7		6	90·7	± 0·3	"	16,250	15,950	121·40	131·4	"	7·60	16160	
8		6	98·2	± 0·2	"	17,600	17,280	215·9	80·0	"	12·5	17100	
9		–	–	–	–					"		18600	

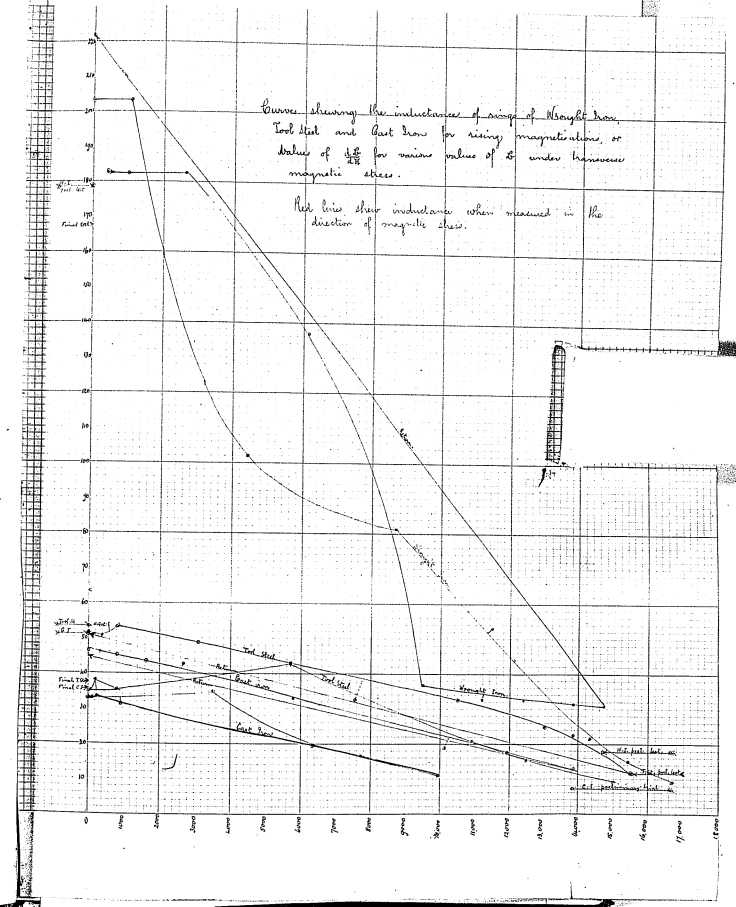
Plan & section of Rings Full Size.



27·3
16·0
8·3 × 0·03 = 0·25 % = 1 + 0·0025

22 × 0·0025 = 0·05 ·4

2·2 = 2·2005 ·4



The inductance of a ring of radii 9.75 and 2.6 with 289 turns and a depth of 1.2 should be

$$2 \times 289 \times 289 \times 1.2 \times \log_e \frac{3.75}{2.6}$$

$$= 2 \times 83{,}520 \times 1.2 \times 0.3667 = 73{,}500 \text{ cms} = 0.735 \text{ Kilomts}$$

the value found being 0.929 .

Experiments on the Permeability of Iron at right angles to imposed magnetisation.

To measure the difference of magnetic permeability in directions coincident with and at right angles to imposed magnetisation in iron took four rings of dimensions shown

No. of Ring	Material	A cms	B cms	C cms	Mean Diam cms	× sectional area Ferron	Vol. by formula c.c.	Weight in air grammes	Weight in Water grammes	Vol. by weight c.c.	Sp. g.
1	Pine wood	5.20	7.42	1.13	6.36	1.198	23.94	10.704	–	–	–
2	Wrought iron	5.22	7.42	1.12	6.32	1.232	24.465	188.915	164.200	24.715	7.6444
3	Best "	5.22	7.42	1.12	6.32	1.232	24.465	172.270	148.050	24.220	7.11
4	Tool Steel	5.22	7.42	1.12	6.32	1.232	24.465	191.310	166.865	24.445	7.826
									m	24.400	

All these rings were wound with one layer of #28 silk-covered copper wire 0.01142" count to 0.018" (0.03361 to 0.04577) over an wrapping of oil paper to keep the wire from the ring. The surfaces of the rings were not polished but were planed true and smooth. The number of turns of this wire was 289 on each ring = $\frac{289 \times 12}{12}$ = 28.8 ft say 28.8 ft with one + slack @ 0.0527 per ft = 2.635 ω. The resistance and weight were

No. of Ring	Material	Weight in Wind	Weight in water	Weight of wire added	Res. of coil	Temp. of Bi coil		Σ(D²−d²) superficial mm.	D²	d²	D²−d²
1	Wood	29.030	10.714	18.296	2.15ω	22.5°C.		28.47	55.056	28.090	26.966
2	W. I.	207.85	188.915	18.935	2.17ω	22.5°C.		21.845	55.056	27.248	27.808
3	B. I.	190.90	172.270	18.630	2.21ω	22.5°C.		21.845	55.056	27.248	27.808
4	T. St.	210.92	191.31	19.61	2.21ω	22.5°C.		21.845	55.056	27.248	27.808

The inductances of these rings was measured when removed from the neighbourhood of magnetised bodies with the following results.

No. of Ring	Ratio of bridge	Res. Ard @ 27.3°C	Res. add @ 4°C.	Capacity for balance	Inductance Henrys	Magnetic Potentiometer	ψ	ψ²	Σψ²	Probable error of mean	τ_m
1 Wood	1000/10	2.196	2.250	0.043 μ	9.675×10^{-5}	0.9285	−0.0390	0.001521	0.003267	0.000102	0.000149
		2.210	2.264	0.0442	9.588		−0.0223	0.000497			
		2.215	2.269	0.0440	9.076		+0.0210	0.000441			
		2.216	2.270	0.0440	9.080		+0.0205	0.000420			
		2.218	2.272	0.0440	9.088		+0.0197	0.000388			1.5%
							1.4142 × 0.0149				
2 Wrought iron	1000/100	2.205	2.259	0.750	1.694×10^{-2}	167.5	−1.9	3.61	29.97	10.11	4.519
		2.200	2.254	0.723	1.630		+2.5	2.25			2.70%
		2.229	2.283	0.730	1.667		+0.5	0.25			
		2.229	2.283	0.742	1.694		−1.9	3.61			
		2.229	2.283	0.740	1.690		−1.5	2.25			
			147	4.97							
			5.00								
			4.97								
3 Best Iron	1000/100	2.262	2.317	0.226	5.236×10^{-2}	53.40	+1.54	1.032	4.588	1.547	0.69
		2.262	2.317	0.230	5.329		+1.11	1.232			1.29%
		2.265	2.320	0.235	5.452		−1.12	1.254			
		2.267	2.322	0.230	5.341		−0.01	1.020			
		2.267	2.322	0.233	5.341		−0.01	0.000			
4 Tool Steel	1000/100	2.256	2.310	0.275	6.355×10^{-2}	53.26	−0.29	0.084	10.944	3.690	1.65
		2.268	2.323	0.260	6.039		+2.97	8.24			2.61%
		2.265	2.320	0.275	6.381		−0.56	0.30			
		2.269	2.324	0.275	6.341		−0.65	0.42			
		2.254	2.309	0.280	6.466		−1.38	1.90			
			63.5	11.89							

Experiments on the permeability of iron in a direction at right angles to imposed magnetisation.

In these inductance ~~experiment~~ measurements, recorded on the last page the resistance of the leads was 0.090ω, and the current would be approximately $\frac{14 \times 0.75}{100 + 3} = \frac{3}{103} = 0.029$ amps, while H would be approximately

$$\frac{289 \times 1.257 \times 0.029}{3.14 \times 6.38} = \frac{10.53}{20.03} = 0.53$$

L in wrought iron would be $\frac{167.5}{0.93} \times 0.53$ i.e. as shown in the next table.

The reason for the small precision of these inductance measurements, particularly in the case of wrought iron was the unsteadiness of the spot, and in fact the slow change of magnetisation of wrought iron for such low values of H, rendered accurate determinations of inductance impossible.

No. of Ring	Inductance Kilometres	μ	H	L						
1	0.9285	1	0.53							
2	167.5	180.4		95.62						
3	53.14	57.5		30.48						
4	63.26	68.14		36.12						

These rings were then placed between the poles of the large electromagnet in successive measurement, one at a time, with their planes at right angles to the magnetic axis. The polar faces are planes 7.14 × 7.3 and thus completely cover the iron in the rings when the latter are placed (concentrically) between them to their magnetic axis. The pole in each measurement were about 1.6 apart (1.4 at the top and 1.8 at the bottom)

To measure the induction passing through the rings in a direction normal to their planes, five turns of silk covered copper wire diam. 0.012" (0.0254) covered to 0.014" (0.035) wound the ring externally and five similar turns internally. The five exterior turns were laged over tapes, in the center of its breadth and in a plane parallel to that of the ring surface. The interior turns were wound over a slightly conical core about 4.85 in mean diam. and about 1 cm thick which when wedged into the ring held the five turns accurately close up to the iron.

The dimensions of these turns are given in the next table.

No. of Ring	Material	No. of turns	Total length of wire	External Diam. mean	Diam. mean	Rings area	Diam. of turns mean	Area.	Length of turns working spec	Area of turns working spec	Diam. of tapes. Tapes
1											
4	Wrought Iron	5	126.7	25.34	8.064	51.07	7.42	43.244	0.322	7.30	7.65
3	Cast	"	122.4	24.48	7.790	47.66	7.42	43.24	0.185	4.42	
2	Cast Iron	"	122.4	24.48	7.790	47.66	7.42	43.24	0.185	4.42	
					Internal	Turns					
											Diam. of wire before covering
4	Tool Steel	5	77.47	15.494	4.931	19.10	5.22	21.40	0.145	2.30	5.0
3	Cast Iron	"	77.46	15.492	4.931	19.10	5.22	21.40	0.145	2.30	4.95
2	Wrot iron	"	77.46	15.492	4.931	19.10	5.22	21.40	0.145	2.30	4.95

Experiments on the permeability of iron in a direction at right angles to imposed magnetisation.

The inductance of these rings was then measured in the same manner as before when the electromagnet was unexcited and when powerfully excited, so as to obtain a rough determination of the limiting effect. The current thro' the magnet coils was either 0 or about 20 amperes.

No. of Ring	Ratio of B.	Res. obtd. μ	Bonds	Current on magnet	Inductance Henries	μ	Res. obtd	Bonds	Current on magnet	Inductance	μ_c	$\frac{\mu_c}{\mu}$	H
2 W.I.	10000/10	4·465	0·4	0	178·6	17·4	4·465	0·04	20 amp	17.86	17.4	10	0·5
3 G.I.	10000/10	4·522	0·113	0	57·1	49·8	4·522	0·016	"	7·236	7·05	7·25	
4 T.St.	10000/10	4·514	0·118	0	53·26	51·9	4·514	0·030	"	13·542	13·2	3·93	
1 Wood	10000/10	4·464	0·023	0	1·027	1	4·464	0·023	–	1·027	1	1·0	

These measurement were next repeated more carefully as follows, viz. including the determination of the induction through the ring and inside it. Corrections are introduced for the winding space, which prevents the five measuring turns from fitting the ring closely. The results give the diminution in μ for H = 0·5 round the ring for any given value of H passing through the ring normal to its plane.

Finally, the exterior and interior 5 turns of exploring wire were removed and the rings wound with two layers of cotton covered wire (see later) 0·017" covered to 0·026" (0·043 to 0·066). The particulars concerning this winding are :—

No. of Ring	Material	Turns on 1st layer (outside)	Turns on 2nd layer (outside)	Total turns	Turns per cm. mean circ.	1·257 × Turns per cm.	Mean inst. diam. over wire	Mean int. diam. over wire	Mean diam. of wire only	Mean diam. of wire only	Mean of ext. + int. diams.	
2	W.I.	101	92	193	9·626	12·10	4·00	8·3	20·05	6·38	6·15	
3	G.I.	101	91	192	9·576	12·04	4·25	8·4	20·05	6·38	6·33	
4	T.St.	113	107	220	10·97	13·785	4·20	8·35	20·05	6·38	6·28	

Under these conditions, the three rings were connected in series and their induction at observed current strengths determined in the usual manner, the secondaries being connected successively to the ballistic galvanometer while the current was reversed in the primary circuit. The inductance by bridge was also determined at each step. The general result gives the measured inductance of the ring for any given value of H along the ring or normal to it.

After these results were obtained the inductance of the ring in air 22nd Apr. 90 with :—

No. of Ring	Material	Ratio of Bridge	T.B.	Temp. of air	Res. obtd	Bafy	Inductance Henries	Original Inductance	
1	Wood	10000/10			2·135 ω	0·048	0·9684	0·9285	
2	W.T.	10000/10			2·29	0·700	148·47	167·5	
3	G.I.	"			2·170	0·159	35·50	53·4	
4	T.St.	–			2·179	0·168	37·60	63·26	

Measurements of Inductances of rings at right angles to Direction of Magnetic action in Multiple Coils.

i Coils all in series @ 25·5°C Mean φ 0·1409 g

Secondary E.M.F.	T sec	EMF at Bordeaux	Q_1 $\times 10^7$	No. of Turns	Mean Turns	r_m	Value of $\frac{r_m}{a}$ =
2.C.C.	25·5°C.	2.5226	0.4079	1·1·67	8	101·9	±0·7	1·145×10⁻³

$\varphi_1 = \frac{52250 \times 10^{10}}{4 \times 2.5 y} = 5{\cdot}08_m \times 10^7 Q$

$\varphi_3 = \frac{t \times 10^7}{10} = 10^7 \times Q_1 r = 5{\cdot}250 \times 10^{10} \times Q_1 \times 10^{-7} = 5{\cdot}25 Q$

$\varphi_2 = \frac{\pi q \times 10^2 \times 10^{-1}}{10}$

Res of Coils 2·375 Ω
" " " 0·1146 Ω
" " " 0·2495 Ω

Coil No.	Deflex. Galv. in C.G.S.	Times	Current in E. magnet.	No. of Turns	Mean Turns	r_m dia.	Res. of Galv. Ckt.	Q	T	φ Eqt. = 1250	Φ
			Coil #1								
1	6·45'	0·11836	0.089	1	3	-	5·250	3·435×10⁻⁷	2·5	31·20	25·3
2	13·45'	0·24447	0.1645	1	3	-	-	3.435		31.2	25·3
3	29·45	0·57¼' 0·09¼ 1·47¼	0·438 0·1455 0·394	1	7	-	-	8·01		72·76	59·1
4		2·198 0·350	1·70 1·16 } 1·48	1	5	-	-	5·725		52·0	42·2
5		0.438 0.130	2·197 2·172 } 1·95	1	57	-	-	65·26		592·0	48·2·0
6		5·73 1·39	3·617 2·382 } 3·51	1	83	-	-	95·04		863·0	70·10
7		1·05 1·10	5·15 2·555 } 5·85	1	90	-	-	103·1		936·0	76·0.0
8		2·35 2·20	14·87 11·31 } 11·59	1	86	-	-	98·47		89·5·0	72·7·0
9		3·68	18·6	2	78	±0	-	89·32		811·0	65·8·0
10		0		-	-						

Coil #3 (Inductive) No. of Turns	Mean Turns	r_m dia	Res. of Galv. ckt.	$\frac{a}{\pi}$	φ	Mean value
2	0	-	5250	0	0	1·12.05
3	2·6	±0·9	"	2.477×10^{-3}	1.667×10^{-3}	
3	6·3	±0·5	"	7·211	3·787	
3	24·8	±0·1	"	30·69	16·11	
3	66·5	±2·2	"	76·15	39·97	
3	76·3	±0·3	"	87·38	45·86	
3	81·7	±0·5	"	93·52	49·11	
3	93	±0·8	"	106·5	55·91	
3	93	±2·4		106·5	55·91	
-	-					

No. of Obs.	Corrected int. φ	Corrected int. Φ	Coil #3 No. of Turns	Mean Turns	r_m dia.	Res. of Galv. ckt.	Q	Φ	Correction for winding φ	Corrected Φ	Φ − φ Tabulation φ	Φ in mm.	Ratio of Radius	Res. dec.	Rad.	Inductance Henrys
1	0	0	2	16·5	±0·4	5250	18·9×10⁻⁷	99·22	0	99·22	99·20	5·54	1000/100	4·5559	0·400	18236
2	17·51	81·8	3	41·7	±0·5	"	47·75	25,070	360	24,710	22·960	1050		4·5554	"	182.16
3	42·43	195·3	3	104·2	±0·5	"	119·3	62,630	877	61,753	57,510	2630	T.B. 27·5°C.	4·5557	-	182.25
4	18,050	8423	3	45·0	±0	30,250	5653	155,900	3728	152,172	136,120	6140		4·560	0·300	136·8
5	44,780	20,93	3	75·5	±0	"	86·45	261,500	9258	252,250	207,470	9500		4·568	0·080	36·54
6	51,380	24,02	3	88·5	±0·2	"	101·3	306,400	10,620	295,780	224,400	11,190		4·568	0·075	34·26
7	55,030	25,72	3	97·3	±0·3	"	111·14	337,000	11,370	325,630	270,600	12,390		4·573	0·075	34·30
8	62,640	29,28	3	109	±0·4	"	124·8	377,500	12,940	364,560	301,920	13,820		4·573	0·072	32·91
9	62,640	29,28	3	115	±0	"	131·7	398,400	12,940	385,460	322,820	14,780		4·620	0·071	32·80
10	-	-	-	-										4·620	0·480	221·8

Bar: reading at time of seal 75·655
·0444
75·699 @ 26·4 °C.
26·4 × 0·00017 × 75·7 = ·3140
76·278 @ 0°C.

Bar: reading at culmination 75·660
·0444
75·704 @ 27·8 °C
27·8 × 0·00017 × 75·7 = ·3558
75·268 @ 0°C.

Res: of Galv. @ temp. of B (26·4°C) 5523 = at time of seal. N.B. This includes 14 = added for one side for multiple bal.
D.B. H.B. Diff. Galv. 2 each
5521 ÷ 2 = 2760·5 = each coil.

Res: of Galv. @ temp of B (28°C) 5540·5
when culminating 3·3
(28 − 26) = 2 × 0·03 = 0·06 × 55 = 3·3 5543·8
2·4 bal
5541·4 ÷ 2 = 2770·5 = . .

The red wire is soldered to the end of the outside cylinder
" black " " " " " " " inside "
" yellow " " " " " " " " middle between " "

Sensibility of Diff. D.B. H.B. Galv. such that a change of 2 in bal: produces 1 div. deflation. Scale read with aid of lens

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H_2O should boil @ 99·76 °C. at pressure of 75·35 cms Hg.

Temp. observed in water bath in ebullition 99·05C
correction for Therm. + ·6
Corrected indn of Thermometer 99·65 Std. # 1.

0·000 1623 × 25·1 = 0·004073

Temp. of Water bath at time of sealing 23·65
Std. # 1 Thermometer correction − 0·1
23·55
278
Abs. temp. 296·55

Took a tube similar to that sealed into bulb, with same attachment (open one) and found that its contents in Hg. were 5·281 gms ÷ 13·596 = 0·388 c.c.

$75 \div 0.388 = 193.3 \quad \frac{1}{193.3} = 0.005177$

$3\beta = 2.8 \times 10^{-5} \quad t = 5.0 \times 10^{-5} \quad 3\beta t = 8.4 \times 10^{-5}$ } 0·01357

Experiments on the temperature-coefficient of Copper.

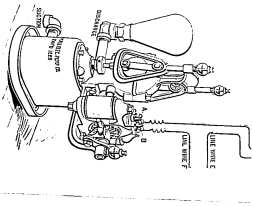
13th Apr. 1890.

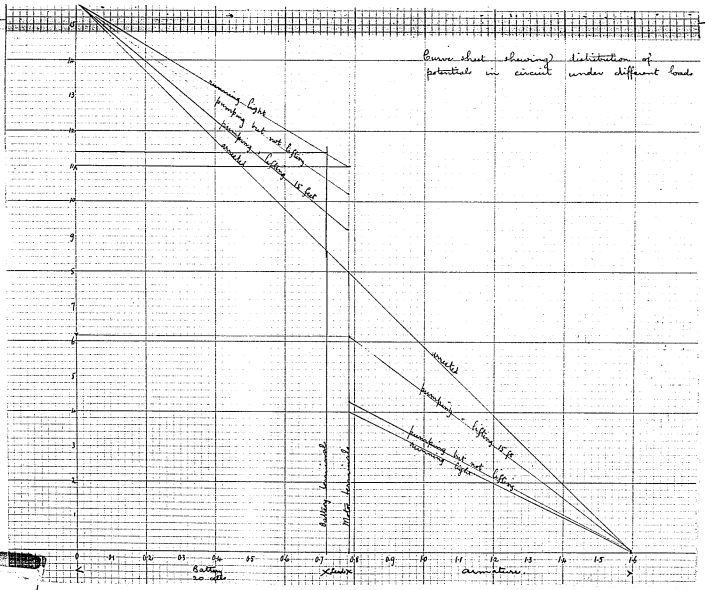
The entire air-thermometer apparatus was dismantled on the 10th, and all its parts cleaned, and examined. The mercury was filtered, and the calibrator index tube of diam: 0·303" (0·770) ext, and 0·207" (0·526) internal, replaced by a longer one of diam 0·295" (0·75) ext. and 0·219" (0·556) internal. The bulb itself was cleaned, and a new tube sealed into it about 16 cms long, with a total equivalent capacity equal to 20 cms. Its diam is 0·24" (0·6) externally, 0·07" (0·18) internally, and its total contents 0·4 c.c. The bulb was then raised to a temp. of about 200°C for an hour under a vacuum to withdraw all moisture from the interior and finally filled with dried air. The apparatus was then remounted. The fiducial mark for the mercury column in the vertical tube leading to the bulb was fixed at a point where the narrow tube above described was joined to one of larger calibre 0·273" ext. 0·205" int. diams. The object of this was to secure less friction in the rising or falling column, this having been a source of inconvenience in the previous measurements, and possibly also of error.

It was then decided to compare the indications of the instrument with those of the mercurial standard thermometer and the following series was taken with that object. The heating bath was of distilled water, raised to the boiling point.

No. of Obs.	Times	Temp. of Room + Bridge	Obsd. res. of Galv. coils	Obsd. res. of 1 ft. of tube. Adopted	Obsd. res. of 1 ft. of tube. Adopted	Ratio of change	Balance between coils	Ratio to 1st	Bath: Ready.	Rise of Hg.	Temp. of Hg.	Coeff. for temp. Hg.	Corrected rise of Hg. at 0°C	Coeff. K.
1	20·40		20·281	10·1815	10·1680		2 =	1·0009	10·716		25·1°	1·00407	10·760	
2	21·142				1·0014				12·689	1·972	25·3	1·00411	1·964	0·02605
3	·50								15·612	4·896	25·6	1·00416	4·875	0·04147
4	·55								18·884	8·168	26·	1·00422	8·134	0·10795
5	22·01		1	1	1				22·786	12·070	26·4	1·00429	12·020	0·1595
6	·11		2	2	2	Mean. 1·293			27·570	16·854	26·7	1·00433	16·788	0·2228
7	·22		9	8	9				29·894	19·088	27·0	1·00438	19·010	0·2523
8	·25		5	9	5				30·112	19·396	27·2	1·00441	19·312	0·2563
9	·32		20·254	13·128	13·170		9 =	1·0032	30·258	19·542	27·2	1·00441	19·460	0·2582
					1·0032				19·543	108·958				
										90·144				
										198·430				

No. of Obs.	1+(t−1)·0041	Corrected Normal Abs. temp	Corrected Abs. temp at obs.	Temp. °C by air Thermom.	Rise of temp. °C by air	Res: added for balance	Res. in Galvanom.	Res. of end Galv. coil	Ratio	Ratio of res.	Coeff. per cent
1	1·00035[illegible]	296·55	296·85			12·95 (a)	4056	2761	0·6092		
2	1·00085[illegible]		296·65	304·38	7·53	1181 (b)	3943	2762	0·70048	1·03903	0·03708
3	1·00085[illegible]		296·81	306·01	9·46	1011 (c)	3774	2763	0·7321	1·07528	0·07983
4	1·00[illegible]		296·98	329·05	32·50	845 (d)	3609	2764	0·7659	1·12510	0·03846
5	1·00216[illegible]		297·19	344·59	48·04	655 (e)	3420	2765	0·80848	1·18788	0·03906
6	1·00302[illegible]		297·45	363·72	67·17	447 (f)	3213	2766	0·86088	1·26466	0·03910
7	1·00342[illegible]		297·57	372·65	76·10	380 (g)	3148	2768	0·87928	1·29161	0·03832
8	1·00361[illegible]		297·58	373·55	77·30			2769	0·87960	1·29217	1·00377[illegible]
9	1·00350[illegible]		297·59	376·43	77·88	378·5 (h)	3148·5	2770	0·87978	1·29242	1·00373[illegible]
			2377·82	2768·68	396·28						
			297·2·40	297·24							
				396·28							


LINE WIRE C
FIELD WIRE F
B
Wheatstone's bridge
Galvanometer
Battery


Curve sheet showing distribution of potential in circuit under different loads
pumping light
pumping but not lifting
pumping & lifting is fair
works
works
pumping & lifting is fair
pumping but not lifting
pumping light
Battery resistance
Motor resistance
0
·01
·02
·03
·04
·05
·06
·07
·08
·09
·10
·11
·12
·13
·14
·15
·16
Battery
Armature
X

Test of 20 Edison-Lalande cells of the double plate 300 chour pattern on a Hall pump motor.

16th Apr. 1890.

The small Hall pump has two cylinders which are driven from a crank shaft between them, which is itself driven by a worm on the motor shaft. The motor is geared 50 to 1, and ordinarily makes 2500 revs per min: when supplied by 100 volts. The motor drawings and calculations are shewn on pages 144-3 book II. The stroke is 1·75" (4·444) and the cylinder diam: 1·75" (4·444) area 2·41 sq in 15·48 sq cms, so that at each revolution of the shaft 8·444 c.in. (137·5 c.c) are discharged. A gallon being 3786 c.c. = 0·03637 gallons per rev: n revs per min: are therefore 2·178 n gallons per hour. Each revolution also lifts 0·3 lbs: so that n revs per min at a lift of f feet are equivalent to 0·3 . n f. foot-lbs per min.

Speed of shaft r.p.m.	Capacity per second	P.D. at M.T.	Current in arm:	Current in field	Power absorbed in arm:	Power absorbed in field	E.M.F.	Res: battery	Res: leads	Power generated by battery	Power adsorbed by battery	Power generated in arm:	Eff: of arm:	Eff: of arm:
		volts	amps	amps	watts	watts	volts	ohms	ohms	watts	watts	watts		
70 p.m.	Discharge	12·0	3·1	0·75	37·2	9	15·8	0·72	0·0650	57·0	9·1	9·5	0·84	
57	Half charge	11·0	4·48	0·68	49·3	7·5	16·0	"	"	82·5	20·6	7·4	"	
0	Amalg	7·9	9·7	0·6	76·6	5	16·0	"	"	164·8	83·3	0	0·81	
59	Pumping 40	10·2	5·3	0·66	53·1	6·7	16·0	"	"	95·3	27·9	5·9	"	
34	" 15 ft	9·2	7·00	0·6	69·9	5	15·6	"	"	128·0	52·8	3·04	"	

Speed of shaft r.p.m.	E.M.F	P.D. at battery terms	P.D. at motor	E.M.F. generated	fall of pot: in battery	fall of pot: in arm:	Power wasted in arm:	Power wasted by accumulator	Nett eff: E.M.F. / E.M.F.	Gross eff: E.M.F. / pot: at M.T.	Speed of calculation shaft for 100 volts	E.M.F. generated per revs	Total revs of wt	
70	14·8	12·8	12·0	9·5	2·93	2·5	7·75	29·46	71·7%	79·15	3500	272×10^{-3}	0·72	
57	16·0	12·3	11·0	7·4	4·05	3·6	16·1	33·16	46·3	67%	2850	2·59	0·065	
0	16·0	8·6	7·9	0	8·09	7·9	76·6	0	0	0	0		0·81	
59	16·0	11·3	10·2	5·9	4·68	4·3	22·8	31·2	36·9	58%	2550	2·31	1·595	
34	15·6	10·1	9·2	3·04	6·444	6·16	46·8	23·1	19	33	1700	1·79		

Succeeded in obtaining fair pumping through 100 feet of iron pipe 3/4" int: diam: laid horizontal and 15 feet vertically at 34 revs per min = 7·4 gallons per hour. This was the limit. A few inches higher pumping stopped the motor entirely. An improvement can be made in the compounding of the fields, but otherwise it will be necessary to use a finer thread on the worm.

Trial of the Melting point of a fine Platinum wire fuse for Battery purposes.

16th Apr. 1890. Platinum wire 0·0025" (0·00635) in diam, suspended horizontally in air

Trial No.	Length wire cm	Ghach	Amp.	P.D. across "Volts"	Res. of wire	Res. per cm.	Ratio of Res. to wire cast	Condition	Energy per cm. Watts	Energy per cm. Sp. cm per cm	Energy per sq. cm			
1	22.85	0.035	0.870					—		0.01995				
2	22.85	0.045	0.237					slightly shade						
3	22.85	0.160	0.808					red ht						
4	22.85	0.180	0.909					broke						
1	8.80	0.06	0.303	2.8	9.24	1.050								
2		0.09	0.455	4.25	9.34	1.062								
3		0.11	0.556	5.55	9.99	1.135		broke white						
1	6.07	0.06	0.303	1.75	5.75	0.947								
2		0.09	0.455	2.9	6.37	1.050								
3		0.11	0.556	3.85	6.92	1.140								
4		0.16	0.808	6.1	7.55	1.244		bright red						
5		0.180	0.909	6.8	7.48	1.232	1.30	broke (fused)	1.018		50.9			

Experiment on the Local Action of Zinc Plates in NaHO solution.

To ascertain how far the cast and rolled zinc battery plates suffered respectively from local action from of each were immersed in solution (of NaHO in water) of the usual strength, on the 17th Apr. 1890. their weight were as follows:—

Rolled zincs nos 1 303.5 grammes
2 315.75 "
3 317.5 "
4 301.5 "
} 619.75, 633.25, 619.25

Cast zincs - 5 1232.75 "
6 1229 "
7 1235.25 "
8 1303. "
} 2462.2, 2463.2, 2538.7

Weights of these plates (dry) at different dates

Plate No.	27. III. 90	31. III. 90	29. III. 90	8 V. 90 Stim. Res. Exc.	27. V. 90	27. V. 90 immersed 4 days							
		4 days	12 days	21	60								
1	303.5	303.3	303	297.1	307.6	302							
2	315.75	315.8	314	308.8	313	311							
3	317.5	317.5	316	310.2	314.3	312							
4	301.5	300.8	300.25	300.3	307.8	295.75							
	12.38.25	12.36.4	12.35.25	1210.4									
	309.56	309.1	308.32	302.6									
5	1232.75	1233	1232	1226.5	1232.5	1231.5							
6	1228.	1227	1226.25	1219	1221.4	1224.							
7	1235.25	1234.5	1233.5	1226.2	1228.9	1231							
8	1303	1302.8	1302.25	1297.0	1296.3	1300							
	4999.0	4997.3	4992.0	4968.7									
	1249.75	1249.3	1248.0	1242.2									
Diff.		0.46	1.24	7.0									
		0.45	1.75	7.5									

$$3\beta = 0.0001815 \frac{p_1}{p_0} - \frac{p_1 - p_0}{p_0 (t_1 - t_0)}$$

#1

$$\frac{0.0001815 \times 108.6705}{108.6705} - \frac{108.8705 - 108.6705}{108.6705\,(132.8)}$$

$$0.00017783 - 0.0001521\overset{2.2}{7}$$

$$= 0.0000\underset{\sim}{2566}$$

#2

$$\frac{0.0001815 \times 84.4191}{86.1201} - \frac{86.1201 - 84.4191}{86.1201 \times 132.8}$$

$$0.00017791 - 0.0001148\overset{(1.7010)}{7}3$$

$$0.0000\underset{\sim}{2918}$$

Standardisation of 4 Clark Cells and 1 Wiet Daniell cell belonging to Messrs Bergmann & C.

18th Apr. 90.

Potentiometer employed. Our two Mainhard standard cells in perfect agreement. Temp. 24·1°C by their thermometer. = 1.4280 volts. @ 24°C.

Wiet Daniell cell. Temp. of solution in central bottle 21·4°C 1.0774 v.

Later " " " 22·4° 1.0750.

" " 23·3° 1.0770.

Reversed Potentiometer readings to check accuracy, accordance perfect.

Cell	1st series	Discrepancy	2nd series	Discrepancy	3rd series	Discrepancy	Mean Discrep.
Our Standard	1.4280		1.4280		1.4280		
Bergmann 1	1.4296	+0.0016	1.4290	+0.0010	1.4286	+0.0006	+0.0011
" 2	1.4130	−0.0150	1.4120	−0.0160	1.4124	−0.0156	−0.0152
" 3	failed	—	failed		0.4074	failed	
" 4	1.3490	−0.0790	1.3490	−0.0790	1.3500	−0.0780	−0.0787

Temp. of air 23°C.

Cells in box with no thermometer hole, in room for one hour, but exact interior temperature uncertain.

Measurement of the Coefficient of Expansion for the glass bulb employed in the experiments on conductivity

18th Apr. 90.

Two bulbs of the same description and quality of glass were blown and drawn out at one end to a fine tube. These bulbs were then filled with good mercury and their temperature when quite full noted. They were then weighed. They were next heated in mercury on a sand bath to a considerable temperature and after cooling again weighed. Their necks being above mercury in the heating process they disgorged all the excess due to dilatation. Finally the bulbs were broken at the neck, emptied and the glass weighed, the entire results being as follows.

No. of bulb	Weight of glass	Temp. std. when full	Ht. corrected for thermom. stem	Weight of Hg at low temp.	Weight of Hg at high temp.	Temp. std. when full hot.	Ht. corrected for thermom. stem	Weight of Hg at high temp.	Weight of Hg contained	Loss of Weight	3β	Mean 3β	Weight
1	10.9305	25.5°C	25.4	119.801	108.8705	157.°C	158.2°C	117.6010	108.6705	2.200	2.0266×10^{-4}	2.0266×10^{-4}	1
2	6.6809	24.6°	24.5°	92.8010	86.1201	"	"	91.100	84.4191	1.7010	2.9182×10^{-4}	2.9182×10^{-4}	2

Giving weight 2 to obs. 2 and weight 1 to obs. 1

The mean result is $3\beta = 2801 \times 10^{-8} \pm 113$

1st obs	2566	Mean 2801	v	235	v^2	55225
v^2.	2948		v	189		14161
					Σv^2	69386
					Σpv^2	83547

$\sqrt{\ } = 289 \times 0.67449 = 195$

$\div \sqrt{3} = 1.732 = 113$

Reduction of Ballistic Galvanometer to Absolute Measure.

Scale	Temp.	Earth's Field	Reduction factor	Q	No. of turns	Mean Throw	τ	Q	Q from Table	Temp.	Mean
Lab.	23°C	2·583	$\frac{2.583}{1.4\times10^{-3}}$	1.4×10^{-3}	5	103·5	±0·1		1.4×10^{-3}		
	23°C	2·583	$\frac{2.583}{1.4\times10^{-3}}$	1.4×10^{-3}	5	103·5	±0·1		1.4×10^{-3}		
									1.4×10^{-3}		

$$\Phi_1 = \frac{Q \times \tau \times}{2\pi N}$$

$$\Phi_2 = \frac{\Omega}{10 \times r}$$

Set No. 1 — Inductance coil

No.	Deflection Galv. in ½ in. scale	Temp.	Correction E. Magnet	No. of turns	Mean Throw	Dev.	Res. of Galv. cct	Q	Φ	Φ_2
1	0	0	0	–	–					
2	6·40	0·11655	0·08868	1	5	–	5250	5.703×10^{-3}	51·8	42·
3	8·20	0·14796	0·18465	1	1	–	.	1·141	10·4	8·4
4	12·20	0·21650	0·16230	1	2	–	.	2·282	20·8	16·8
5	21·	0·37881	0·28860	1	5	–	–	5·703	51·8	42·
6		0·10081	0·585	1	10	–	–	11·405	103·6	84·1
7		0·0422	0·964	1	8	–	–	14·83	134·7	109·3
8		0·0422	2·693		32	–		36·5	331·6	269·2
9		0·0975	4·910	1	45	–	5250	51·33	466·3	378·6
10		4·10	20·70	1	57	–	.	65·0	590·4	479·4
11		0		–	–	–	–	–	–	–

Set No. 2 — Condenser

No.	Deflection Galv.	Temp.	Correction E. Magnet	No. of turns	Mean Throw	Dev.	Res. of Galv. cct	Q	Φ	Φ_2
1										
2	2·2282	0·0422	0·0422	2	2	±0	5250	2.282×10^{-3}	1198	
3	3·42	0·0633	0·0633	2	3	±0	.	3·42	1795	
4	5·133	0·0844	0·0844	2	4·5	±0	.	5·133	2695	
5	10·84	0·1688	0·1688	3	4·5	±0·5	–	10·84	569·1	
6	17·68	0·2532	0·2532	2	15·5	±0·5	.	17·68	9282	
7	38·78	0·5066	0·5066	3	3	–	.	38·78	20360	
8	64·16	1·0132	1·0132	3	8	±0	(32,250×1) 32,250	64·16	33,680	
9	62·26	2·0264	2·0264	6	6	±0·5	32,250	62·26	32,680	
10	42·43	4·0528	4·0528	6	94	±0·5	32,250	42·43	22,280	
11	58,130									

No.	Corrected Φ	Φ_2	Set No. of turns	Mean Throw	τ	Res. of Galv. cct	Q	Reduction factor	Φ	Correction for winding space	Corrected Φ	$\Phi - \Phi_2$	L in cm	Ratio of Bridge	Resistance Measured	Coeff.	Inductance Henries
1	–	–	–	–	–	–	–	–	–	–	–	–	–				
2	1342	62·7	2	16	±0	5250	1.025×10^{-3}	525	9,582	277	9305	7963	365	1000/100	4·575	0·101	46·2
3	2011	94	2	17·5	±0·4	.	1·936	.	10,480	416	10064	8053	369	27·4	4·639	0·099	45·94
4	3020	141	2	36	±0·8	.	4·107	.	21,560	613	20,937	17,917	820		4·655	0·098	45·63
5	6377	298	3	73·5	±1·2	.	8·385	.	44,020	1317	42,703	36,326	1660		4·651	0·097	45·12
6	10400	486	2	119	±1·9	.	13·57	.	71,230	2145	69,052	58,652	2690		4·668	0·093	43·42
7	22810	1066	3	44·3	±0·5	30,250	50·33	.	152,900	4712	148,188	125,378	5740		4·690	0·090	42·47
8	38,810	1814	3	77·7	±0·3	.	88·64	.	269,200	8019	260,181	221,371	10,130		4·707	0·070	32·83
9	38,810 (42,280)	2290	2	93·5	±0·4	.	106·75	.	319,200	10120	309,080	260,060	11,940		4·704	0·038	18·80
10	62,890	2939	2	109·5	±0·4	–	124·9	–	377,900	12,095	364,905	302,015	13,830	27·52	4·716	0·037	18·780
11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4·713	0·095	44·780

Measurement of Inductance of Iron Ring at right angles to the Earth's Field.

Direction of Magnetic Axis

	Ratio	Coeff.	Inductance
	1·1205	∞	
1			E. M. F.
2			Comp. +110
3			3 - +110
4			2 + +110
5			1 - +110
6			1 Comp.
7			110

Reduction of damping to absolute measure

Temp.	Temp.	E.M.F. at 1 volt	Bands	a	No. of Bands	Mean Thickness	Pos. dev.	a per dev.
16°C.	22°C	1·420	1000	1·420 $\times 10^{-3}$	7	123·6	± 0·3	$1{\cdot}157 \times 10^{-3}$

Period of one complete swing of bulkiness results 20 sec. exc.

$$\rho = \frac{5250}{578} \times \frac{1{\cdot}157}{4} \times 9{\cdot}074\ \psi = \frac{30{,}250}{578}\ \psi = 52{\cdot}35\ \psi$$

Measurement of the Induction of Rings at night angles of magnetic dip (Prof. Stark)

No. of obs.	Position of Ring	Correction	Corrected φ	Coil #1 No. of Bands	Mean Thickness	Coil (Inductometer) Pos. dev.	Ratio of Gilbert cst	a	φ	Σ	Coil #2 No. of Bands	Mean Thickness	Pos. dev.	Ratio of Gilbert cst	a	φ
1	0°·00'	-		+	0	-	5250	"	"	-	#	θ	-	5250	-	-
2	6°·20'	0·1139	0·0869	1	0	-	-	"	"	-	1	0	-	"	-	-
3	8°·40'	0·1524	0·1849	2	7·5	± 1·2	"	$8{\cdot}678 \times 10^{-3}$	78·82	64	3	6·7	± 0·3	-	$7{\cdot}75 \times 10^{-3}$	4·69
4	30°·20'	0·5851	3·4495	1	13	-	-	20·82 "	189·1	153·5	3	16·2	± 0·7	"	18·51 "	9·718
5		0·195	0·985	3	73	± 1·4	-	84·44 "	767.	622	3	39·7	± 1·0	"	45·93 "	24·110
6		0·391	1·554	2	7	± 0	30,250	8·098 "	423·8	344	2	18	± 0	30,250	20·82 "	42·980
7		0·670	3·384	1	7	—	"	" "	423·8	"	2	21·8	± 1·0	"	25·22 "	76·290
8		0·950	4·798	1	7	-	"	" "	423·8	"	2	23	± 0	-	26·61 "	80·500
9		0·910	9·648	-	-	-	—	" "	-	-	2	27	± 0·9	"	31·24 "	94·500
10	-	0	0	-	-	-	"	" "	-	-	-	-	-	-	-	-

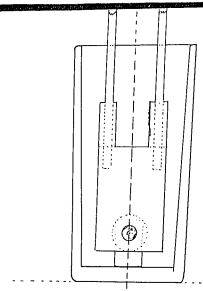
No. of Obs.	Correction φ	Corrected φ	Coil #2 No. of Bands	Position Mean Thickness	Coil Pos. dev.	Ratio of Gilbert cst	a	Φ	Correction for refraction	Corrected Φ	Φ − φ	Σ in mm	Ratio of Bridge	Mean Thickness	Pos. dev.	Ratio of Gilbert cst	a	Φ
1	-	-	0	15·5	±0·7	5250	-	-										
2	-	-	4	15·5	± 0·7	"	17·93	94·10		94·10	94·10	430	10000/100	4·490	0·112		5·02	
3	4·560	213.	4	148·4	± 0·3	-	56·0	294,400	1668	296,068	231,170	1060		4·490	0·113		50·74	
4	10,890	509	5	135·8	± 0·6	-	157·1	824,460	3986	828,446	678,580	3095		4·505	0·118		53·15	
5	27,020	1263	3	333	± 0·4	"	385·3	2023,300	9888	2032,988	1655,590	7570		4·495	0·108		48·65	
6	70,560	3298	2	93	± 0·0	30,250	107·6	325,500	2588	2993,670	2924,210	10500		4·495	0·072		32·37	
7	85,480	3996	2	114·5	± 0·4	"	132·5	400,900	31,200	369,500	2842,020	13,000		4·463	0·073		32·88	
8	90,190	4216	2	121·5	± 0·4	-	140·6	425,300	33,020	392,280	3020,090	13,830		4·449	0·055		24·47	
9	105,900	4948	2	138	± 0·0	"	159·7	483,100	38,750	444,350	3388,450	15,500		4·432	0·050		22·46	
10	-	-	-	-	-	"	—	-	-	-	-	-		4·432	0·031		13·74	
														4·603	0·110		50·63	

Reduction of Observations to other measures

Source of E.M.F.	Temp	E.M.F. of Cell	Resist.	Q	Mag. of Magnet	Mean Mag. Moment	Mag. Field	Q. from Mag.
2 G cells	22.5°	2.159	0.409 Ω	1.1645 ×10⁻⁷	5	101.6	1.18	1.151 ×10⁻⁷

Measurement of the Inductance of Things in the Direction of Magnetization (Ewing)

No.	Time	Alternator	Galvanometer	Lamp	Current	No. of Turns	Mean Thickness	Time	Q	Mass in gm	φ	cos φ	1.257 × turns / cm.	H	μ	Resistance Bridge	Resistance Coil	Reactance	Inductance Henries	
Wrought Iron																				
1	14.40	∞	0	0	0	–	–	–	–	5250 gm	–	–	–	–	–	1000/100	5.805	0.350	203.2	Res. of Iron 0.27 Ω
2	.50	14.40 to 1.10	6°.40'	0.1169	0.098	4	103.6	± 0.3	110,250 ×10⁻⁷	"	1062	879	12.10	1.065	825.5	1000/100	5.807	0.350	203.3	
3	.55	2 - -	16°.30'	0.2462	0.233	6	90.5	± 0.7	104.2 -	30,250	5455	44.29	18.4	2.70	16400	1000/100	5.824	0.175	101.93	
4	15.20	1 - - -	38°.0	0.7513 0.150 0.152	0.089 0.086	4	177.3	± 0.2	201.1 -	30,250	8660	8670	39.70	7.13	12160	1000/100	5.834	0.140	81.66	
5	.35			0.22	1.11	3	66.1	± 0.5	76.09 -	105,250	13,850	11,240	66.70	13.14	839	1000/100	5.8444	0.090	52.61	
6	.50			0.540	2.728	3	84.3	± 0.3	97.04 -	"	14,670	14,340	34.03	33.0	435	1000/100	5.8544	0.037	21.66	
7	16.00			0.853	4.31	3	90.5	± 0.2	105.2 -	"	18,970	15,400	23.3	52.17	295	1000/100	5.980	0.025	14.75	
8	.10			0.9932	1.0[illegible]	2	98.5	± 0.4	113.4 -	"	20,650	16,760	11.9	60.7 121.4	276 138	1000/100	6.023	0.015	9.034	
Soft Iron																				
1			0		7	6.8	2.03	–	5.250 gm				12.014	0		1000/100	5.677	0.056	32.8	Res. of Iron 0.245 Ω
2			6°.40'																	
3			16°.30'		3	6.8	± 0.3	7.829 ×10⁻⁷	"	7.4	57.7	4.25	1.060	54.4	18.8	1000/100	5.855	0.056	32.8	
4			38°		3	19.7	± 0.3	22.68 -	"	22.68	184.1	5.56	2.69	68.4	11.46	1000/100	5.883	0.057	33.54	
5			0.222		4	114.9	± 0.4	132.3 -	"	120.2	975.6	11.99	7.09	137.6	7.26	1000/100	5.938	0.0564	31.53	
6					4	72.1	± 0.3	83.0 -	30,250	43.44	352.7	28.91	13.37	263.8	3.70	1000/100	5.994	0.029	31.78	
7					3	72.0	± 0.4	82.9 -	55,250	79.25	643.4	15.01	32.85	195.9	5.16	1000/100	5.916	0.033	19.72	
8					3	45.2	± 0.1	52.04 -	105,250	94.76	769.4	11.79	51.9	148.2	6.73	1000/100	6.033	0.027	16.29	
9					2	58.5	± 0.4	67.34 -	105,250	12.260	99.52	6.48	60.4 120.8	164.8 82.4	12.1	1000/100	6.200	0.017	10.71	
Test Bar																				
1			0		–	–	–	–	5.250				13.785	–		1000/100	5.858	0.059	34.57	Res. of Iron 0.28 Ω
2					3	7.3	± 0.3	8.40	–	7.63	62.0	4.0	1.212	51.2	19.5	1000/100	5.867	0.060	35.20	
3					3	23.3	± 0.3	26.82	"	24.3.6	197.7	5.05	3.07	64.4	15.5	1000/100	5.877	0.065	31.21	
4					2	2.85	± 0.4	32.75	30,250	1296	1092	10.13	8.12	129.6	7.82	1000/100	5.838	0.061	35.62	Res. 2.21
5					2	117.5	± 0.4	135.3	5250	1224	998	24.4	15.3	370.2	2.70	1000/100	5.901	0.073	43.08	
6					4	115.8	± 0.6	133.3	30,250	8976	5664	3.05	37.59	289.5	3.45	1000/100	5.929	0.035	20.74	
7					3	121.7	± 0.9	140.1	55,250	13390	10,880	2.39	59.39	209.1	4.78	1000/100	6.040	0.026	15.71	
8					3	73	± 0	84.04	105,250	15300	12,420	1.656	121.4	146.6	6.82	1000/100	6.140	0.014	8.97	
9					2	88	± 0.8	101.3	105,250	18,440	14,970	6.54	60.4 138.2	216.6 105.3						



Vertical section through axis of new standard Meter bottle showing zinc in place.

Full size.

Measurement of Resistance of new meter bottles.

12 bottles were made up on Friday 18th April, with laboratory solution and zinc fresh from Silod lake. 1.11 The object of the test was two-fold. 1st To ascertain how much difference would be produced in the resistance of a bottle if the plates were used fresh from the factory without amalgamation. 2nd The difference between the resistance of bottles of two different temperatures.

No. of bottle	Weight empty 18. IV.	Dist. Weight 19. IV.	Sum	Discrepancy 5 - 5	Weight empty 21. IV. 90	Dist. weight 21. IV. 90	Sum of Simple weights	Discrepancy 5 - 5	Gain	Loss	Shunt	Assumed for 1st o	Rise of bottles.
1	51·1626	102·3644			51·0010					0·1626	∞		
2	50·8815		102·3451	+0·0013	51·3725	102·3743	102·3735	−0·0005	0·4910				
3	50·9215				50·7390				0·4178		∞		
4	51·3131	101·6345	101·6343	−0·0002	50·8815	101·6215	101·6205	−0·0010		0·2316			
5	51·0472				51·1180				0·8708				
6	50·3139	101·3611	101·3611	0	50·2467	101·3670	101·3647	−0·0023		0·0672	2ω	hot	
7	50·0057				50·2022				0·3370				
8	50·5572	100·5624	100·5624	0	50·2255	100·5672	100·5677	+0·0005		0·3317	2ω	hot	
9	50·4333				49·9772					0·4561			
10	51·1231	101·5563	101·5564	+0·0001	51·5585	101·5620	101·5617	−0·0013	0·4614		2ω	cold.	
11	51·6575				51·6985				0·4400				
12	51·0275	102·4559	102·4959	+0·0392	50·6990	102·4985	102·4975	−0·0010		0·4385	2ω	cold.	
13	51·5018				51·1570					0·0448			
14	51·6929	103·1950	103·1947	−0·0003	51·7225	103·1795	103·1795	± 0	0·0296		2ω	~~hot~~	
15	50·3799				50·4700				0·1021				
16	52·5905	102·9620	102·9624	−0·0006	52·3020	102·7760	102·7760	± 0	0·2	0·2885	2ω	hot	
17	51·5945				51·8160				0·2215				
18	51·9093	103·5020	103·5031	+0·0009	51·5460	103·3590	103·3610	+0·0020		0·3643			
19	49·5600				49·9920					0·3680	2ω	cold.	
20	51·5570	101·4080	101·4080	−0·0010	51·7865	101·2770	101·2775	+0·0005	0·1995				
21	51·9675				51·6190					0·3185	2ω	cold.	
22	51·4016	103·3691	103·3691	−0·0007	51·6830		103·3220	−	0·2814			cold.	
23	50·2592				Avg. 7970					0·4622	∞		
24	51·0576	101·3198	101·3188	−0·0010	51·5640	−	101·3220	−	0·4862				

The hot box had a temp: of about 58° F and the cold box about 42° F. but the temperature failed in the hot box for a large part of the time. The current was supplied from 1 KHO cell through all the bottles in series and 60ω externally) or about 10 milliampères. The test lasted from 18 o'clock 18th Apr. to 8 o'clock 21st or 64 hour. At the end of that time #5 & 13 & in the cold box & 9 & 10 in the hot box were found in good condition, while all the others were more or less smutted. It was also observed that the black lead figures on the sides of the unamalgamated plates, put on at time of weighing were thickly covered by deposit, much more thickly than on any other part. This was not the case with the amalgamated plate.

This series was taken under favorable conditions. The apparatus was all in good order. The column of mercury in the bulb tube was tapped before every observation, although no friction could be detected. Height of meniscus nearly 1 mm.

Barometer at 19.06 time of reading 76.520 @ 66°.5
index error .0444
76.4756 @ 19.0°.C
$19.0 \times 0.00017 \times 76.56$ 0.247
76.229 @ 0°.C 76.317 + 2.8647 = 79.1817
0.237

Barometer at culmination 76.64 @ 73°.5
.0444
76.596 @ 22.8°
$22.8 \times 0.00017 \times 76.7 =$ 0.297
76.299 @ 0°.C.

No difference in reading observable when the mercury exceed fiducial mark in upward or downward direction.

$t = 300$ $K = 1/15 \cdot \frac{0.14}{0.14} = \frac{0.14}{15} = 0.0093$

$3\alpha = 2.8 \times 10^{-5}$

$3\alpha t = 84 \times 10^{-5} = 0.0084$ $3\alpha t + K = 0.0177$

Obtd temp. of bath when reading 16.75°.C by thermo. 81
.07
16.68°.C corrected reading
273.7
290.38 - abs temp.

Since an error γ at v' gives only, introduces an error of $\frac{\gamma}{v}$ into the coefficient, it follows that the weight of v is $\frac{1}{v^2}$. Also the curve of this method (probably) measures directly with v so that on this account the weight of an observation of $\frac{1}{\sqrt{v}}$. Hence finally the weight of an obs is $\sqrt{v}$. The following table gives results

No.	Coeff. $\times 10^{-4}$	N	$\sqrt{N}$	Δt	$N\sqrt{N}$	$(N\sqrt{N})$ Coeff	General Mean	v	v^2	pv^2	$\frac{v}{(\sqrt{N}\sqrt{\Sigma N})}$	$\frac{v}{\sqrt{\Sigma p}}$
1	0.4097	27.4	5.27	11	5.27	24.120		+0.00558	33.64 x10⁻⁶	177.3 x10⁻⁶	0.1509	0.02196
2	0.3944	42.6	6.53	2	13.06	5.2020		0.00051	0.261	8.515	× 3.0436	= 0.000735
3	0.4038	45.45	7.52	3	22.56	9.1100		0.00027	0.729	16.450		
4	0.4207	72.25	8.50	4	34.00	13.6900		0.0038	14.44	49.100		
5	0.4063	57.1[illegible]	9.33	3	27.99	11.3750		0.0002	4	12.0		
6	0.4172	105.01	10.25	4	41.00	17.1100		-0.0107	114.49	469.400		
7	0.4080	132.05	11.44	3	33.42	13.6390		0.0015	2.25	7.520		
8	0.4144	139.06	11.81	4	47.24	19.5000		0.0076	57.76	273.900		
9	0.4143	154.17	12.42	4	49.68	20.5800	0.4065	0.0078	60.84	300.230		
10	0.4002	169.94	13.04	4	52.16	21.7400		0.0017	2.89	12.400		
11	0.3976	183.71	13.55	4	53.20	21.1300		-0.0037	1.369	73.900		
12	0.3990	187.68	13.68	3	40.44	16.0100		0.0089	7.921	320.300		
13	0.4022	238.52	15.44	4	61.76	24.6100		0.0075	5.625	315.000		
14	0.4022	240.87	15.19	4	60.76	24.2000		0.0043	1.849	44.800		
15	0.4019	246.82	15.65	4	62.60	25.3500		0.0013	1.849	113.300		
16	0.4070	255.26	15.98	4	63.92	26.0200		0.0016	256	16.200		
17	0.4014	255.26	15.98	4	63.92	26.0200		-0.0005	25	1.960		
18	0.4098	255.26	15.98	4	63.92	26.0200		0.0009	81	5.177.0		
19	0.4097	256.44	15.34	3	46.02	18.8600		0.0023	529	33.810.0		
20	0.4088	267.52	16.41	3	49.23	17.6600		0.0032	1.024	47.130.0		
					909.97	366.9120		0.0023	529	23.520		
					1.67	1.32				2,192.260		
										$\sqrt{2192.260}$ = 0.02196		

General result gives coefficient for 1°C by air-thermometer 0.4065 ± 0.00073

No.	Time	Temp. of Bath	Obtd. air temp. after time allowed	Obtd. air temp. after time allowed	Observed mean of both air temps.	Balance added to reduce to	Ratio	Barometric Reading	Temp. of Hg. col.	Coeff. for temp. Hg. column	Corrected Barometric Reading	Press. of Hg.	Coeff. for air
1	19.06	18°	19.6								76.520	76.47 21	0.1[illegible]
2	20.02	19°	19.5	19.9410	0.924	19.8365	5v	1.00187	9.68	20°	9.0877	78.8[illegible]	0.0[illegible]
3	.06		19.6	19.865	0.0255							82.3235	
4	.22		18.5	1.00711					11.9444	21°	11.0034	2.8807	0.1007
5	.29		19.2						15.8244	21.5°	1.0034.07	15.7694	6.7357	0.3964
6	.35	19.4	19.7						19.4230	21.6°	1.0035.06	19.3621	10.3234	0.4095
7	.45		19.5						23.4470	21.7°	1.0035.22	23.3876	14.3289	0.4027
8	.54		20.2						27.3120	21.9°	1.0035.54	27.2562	18.1765	0.4063
9	21.00		20.3	1	1	1			31.9644	22.1°	1.0035.87	31.8947	22.8710	0.4172
10	.10	19.3	20.3	9	9	9	22v		36.8622	22.3°	1.0036.19	36.7294	27.2904	0.4080
11	.18		21.1	6	6	5			40.8544	22.5°	1.0036.52	40.7053	31.6866	0.4144
12	.30		21.8	5	1	5			44.5714	22.8°	1.0037.00	44.4296	35.5390	0.4143
13	.44		21.5						48.6464	23°	1.0037.33	48.4666	39.6279	0.4002
14	.49	20°	21.5						52.1764	23.2°	1.0037.65	51.9765	42.8570	0.3976
15	.56		21.9						55.6064	23.6°	1.0038.20	55.3938	46.3551	0.3990
16	22.04	20.1	22.1						60.338	23.8°	1.0038.63	60.1058	51.0671	0.4022
17	.12		22.1	1.00096					64.208	24.1°	1.0038.96	63.9588	54.6201	0.4022
18	.21	20.3	22.2	19.9551	19.9644	3g.0645	27v	1.00990	67.820	24.9°	1.0038.79	67.5579	58.3702	0.4019
19	.25		22.1		3g.1155	3g.0945			70.4586	23.8°	1.0038.63	70.2147	61.1770	0.4070
20	.40		22.0			0.0025			70.4286	23.7°	1.0038.47	70.2037	61.1772	0.4097
21	.48		21.5						70.4286	23.7°	1.0038.16	70.2037	61.1772	0.4088
22	.55	20.6	21.5						65.4284	23.6°	1.0038.86	65.2037	56.7672	0.4097
									58.3144	23.6°	1.0038.30	58.1078	49.7872	0.4088

No.	V (1.0038)	(1.0038)$^{-1}$ (1.0038)$^{-2}$	Corrected Normal temperature	Obtd. air temp. at observation	Temp. C by air thermometer	Ratio of temp. C to air thermo.	Pres. reduced for balance	Pres. reduced 19.5°.C.	Pressure of Gas cells	Pressure of Gas cells reduced 19.5°.C	Pressure of Gas cell.	Ratio	Ratio of Pressure
1	1.0000		290.4	290.4	16.7								
2	1.037500	1.000515	290.6	301.5	27.8	11.1	1358 (6)	1358 (6)	2671.5	2672.5	4025.3	0.663025	1.0
3	1.038000	1.001208	290.7	316.34	42.64	25.94	1185 (11)	1185 (11)	2670.5	2680.5	3856.4	0.693[illegible]6	0.9[illegible]8
4	1.135505	1.001853	290.9	330.25	56.35	39.85	980 (14)	979.9 (14)	2688.	2665	3661.9	0.73263	1.03[illegible]6
5	1.139048	1.002476	291.2	345.95	72.25	55.55	800 (18)	800 (18)	2697.	2690	3490.	0.77077	1.0092
6	1.239[illegible]	1.003263	291.4	360.81	89.11	70.41	622 (24)	622 (24)	2700	2695	3317.	0.812.68	1.02370
7	1.245[illegible]	1.004095	291.6	378.77	105.07	88.37	462 (31)	462 (31)	2703	2700	3162.	0.85389	1.02412
8	1.32[illegible]	1.004971	291.8	397.69	123.99	107.29	292 (41)	292 (41)	2706	2705	2977.	0.90863	1.03573
9	1.41[illegible]	1.005895	292.0	413.18	139.48	122.78	-5 (60)	-5 (60)	2710.	2711	-2716	1.00157	1.00167
10	1.465[illegible]	1.006833	292.3	427.87	155.17	137.47	-114 (80)	-114 (80)	2712	2713	-2827	1.04206	1.05[illegible]
11	1.51[illegible]	1.007798	292.5	443.64	169.94	152.24	-215 (100)	-215 (100)	2714	2715	-2930	1.07923	1.0555
12	1.562[illegible]	1.007710	292.8	457.41	183.71	167.01	-300 (120)	-300 (120)	2716	2717	-3017	1.11036	1.0[illegible]
13	1.609[illegible]	1.008322	292.6	465.38	181.68	164.98	-370 (139)	-370 (139)	2718	2719	-2989	1.09944	1.0252
14	1.6[illegible]	1.009166	293.1	489.23	205.53	187.83	-335 (150)	-335 (150)	2719	2721	-3106	1.14164	1.0[illegible]
15	1.7[illegible]	1.009860	293.3	504.29	230.59	213.89	-530 (170)	-530 (170)	2720	2723	-3253	1.19482	1.0962
16	1.7[illegible]	1.010505	293.5	515.57	244.67	228.17	-634 (180)	-634 (180)	2721	2724	-3363	1.23480	1.0356
17	1.804[illegible]	1.010980	293.6	528.96	255.26	238.56	-705 (190)	-705 (190)	2721.5	2725.3	-3481	1.27729	1.0238
18	1.808[illegible]	1.010980	293.6	528.96	255.26	238.56	-840 (200)	-840 (200)	2721.5	2725.5	-3566	1.30840	1.0701
19	1.7[illegible]	1.010980	293.3	528.96	255.26	238.56	-842 (200)	-842 (200)	2721.5	2725.3	-3568	1.30922	1.0719
20	1.7[illegible]	1.010980	293.3	528.96	255.26	238.56	-818 (200)	-818 (200)	2721.5	2725.3	-3546	1.31141	1.0730
21	1.7[illegible]	1.010980	293.3	509.14	235.44	219.74	-705 (190)	-705 (190)	2721.5	2725.3	-3431	1.25890	1.0[illegible]
22	1.6[illegible]	1.008808	293.9	461.22	207.52	190.02	-645 (180)	-645 (180)	2721.5	2725.5	-3270	1.19.185	1.0[illegible]
				9479.25	5254.55	5000.05		12620		59,337	70885.7		
					5254.55	3270 =				5,337			
					9479.25	34.65				70,223.7			

Test of a Material whose samples received from Messrs. Bergmann & Co. are marked V. M. C. No. 1. Received 22nd April 1890.

These two samples were similar and in the form of discs 6·5 in diam and 1·0 thick. Brown glazed superficially) and having the appearance of stoneware. These are very brittle and break by fall of two or three feet. The fracture is irregular and almost cryst-alline, much resembling that of sandstone. In the latter it burns the edge of the tool but it drills readily. The thread it bakes is weak and poor. It is not affected by flames but will not burn long when withdrawn. It soaks by oozing across its surface about as much as slate, and the surface glaze is very easily scratched off even by a common brass pin. The weight of one ~~pin~~ disk dry was 70.475 g. in air. This was left to soak in water. Another piece was buried and a third left on the engine plate. The weight of the disk left in water was 70·476 g. after drying on the 26th April. The weight of the other piece was not taken but they were apparently quite unaffected by their treatment. The heated piece only showed a slight change in color.

Experiments on the Electrolysis of Matta.

see p. 28

23rd Apr. 1890. The same bath and general connections were used with a new matta plate. The mean temp of the liquid between the electrodes was 38°C (100.4°F) and the following readings were obtained. The distance between carbon and matta 5".

No. of Obs.	Lamps in cct.	Voltmeter reading	Current amperes	Amperes per sq. ft	Ohmic reading	res.	P.D. due to res.	P.D. due to counter	res. per sq. ft	Cost of comp. per hour	Cost of res. per hour	Total cost.
1	6	1·8	3·283	5·3	0·65	0·2ω	0·86	1·14	0·125ω	1·18 volts	$ 4·10	10·0
2	8	2·0	4·091	6·5	0·81		0·82	1·18			5·04	10·94
3	10	2·18	5·303	8·5	1·05		1·06	1·12		$5.90.	6·60	12·50
4	12	2·35	5·910	9·4	1·17		1·18	1·17			7·20	13·20
5	14	2·52	6·768	10·8	1·34		1·35	1·17			8·38	14·28
6	16	2·70	7·576	12·1	1·50		1·52	1·18			9·39	15·29
7	18	2·80	8·106	12·7	1·605		1·62	1·18			9·85	15·75
8	20	2·90	8·714	14·0	1·73		1·75	1·15			10·86	16·76
9	22	3·05	9·344	15·0	1·85		1·87	1·17			11·64	17·64
10	6	1·90	8·344	5·3	0·662		0·67	1·23				

24th Apr. Mean temp. 50°C (122°F)

No. of Obs.	Lamps in cct.	Voltmeter reading	Current amperes	Amperes per sq. ft	Ohmic reading	res.	P.D. due to res.	P.D. due to counter	res. per sq. ft.	Cost of comp. per hour	Cost of res. per hour	Total cost.
1	8	1·7	4·24	6·9	0·82	0·18ω	0·76	0·94	0·112ω	1·0 vo	4·80	10·10
2	10	1·88	5·00	8·1	0·99		0·90	0·98		$5·30.	5.63	10·93
3	12	2·0	5·81	9·4	1·15		1·05	0·95			6·33	11·63
4	14	2·2	6·67	10·845	1·32		1·20	1·0		Matta changed frequently.	7·27	12·57
5	16	2·4	7·98	12·5	1·58		1·44	0·96			8·69	13·99
6	20	2·6	8·59	13·46	1·7		1·55	1·05			9·36	14·66
7	22	2·7	9·09	14·26	1·8		1·62	1·06			9·90	15·20
8	8	1·8	4·09	6·4	0·81		0·74	1·06			4·45	9·75

$4.8 x + y = 1.8$
$9 \cdot 09 x + y = 2.7$
$5x = 0.9$
$x = 0.18$
$y = 1.06$

500 dr = in of that brass per hour = 0.112
= 89.6 d × 0.776 = 69.5 d f.

Meter Experiments.

The following measurements were made of the Test No. 8. meter 24th Apr. Res: between slip as follows:-

Obs. No.	Slip	Temp. B.	Bridge Ratio	Res: of std	Leads	Total Res.	Temp. of air in crate	Rate of speed	Corrected to 21·1°C.	
1	Left hand	19°C.	1000/100	48·66	2·36	46·30	20·5°	46·295	46·40	21·1 − 20·6 = 0·6
2	"			48·51		46·15		46·145	46·25	0·6 × 0·311 = 0·2328
3	"			48·42		46·06		46·055	46·16	1·002328
4	Right hand			48·53		46·17		46·165	46·27	
								Mean	46·27	

Balance one strip in the meter against our standard 0·01 ω
This standard was measured on 28th Jany 1890 as correct at 27°C.
7th Feby - - - 7°C.
18th June - - - 14°C.

When compared with lower strip results as follow:-

Obs. No.	Shunt combined	Time	Res: of Galv.	Comparing	Temp. of Std.	Res: of Std. at temp.	Balance	added to	Resistance	temp. of strip
1	Lower	11·30	54·00	0·01 ω	27·1°	0·010039	2832	0·01 ω	0·004983	20·5°C.
2	"	11·45	"	Upper	—	—	270	lower	0·006935	Ratio $\frac{L}{U}$ = 1·01
3	"	13·40	53·91	0·01 ω	20·8°	0·010020	2830	0·01 ω	0·004972	20·6°C.
4	"	"	"	"	"	"	2875	"	0·004932	1·0039
5	"	14·00	"	Upper	—	—	260	lower		Ratio $\frac{L}{U}$ = 1·0039
6										

Balanced Platinoid grid used in carrying capacity of conductors against 0·1 standard Platinoid. held by account to be correct @ 14°C.

Obs. No.	Grid.	Time	Res: of Galv.	Comparing	Temp. of Std.	Res: of Std @ temp.	Balance	added to	Resistance	Temp. air
1	Pat. 6 Coil	15·0	53·92	0·1 ω	20·9°	0·10021	2818	0·1 ω	0·004903	20·4°

Made a comparison test for this & meter by) using the grid with shunt resistance of about 4·70 ω in its circuit.
The test commenced 23rd Apr. 90. 12 o'clock. Current 50 & 60 amp.

Thousand plate	Weight 23 Apr. 90	Sums	Weight gained 23.10.90	How placed	Weight 23 Apr. 90	Sums	Weight gained 23.10.90	Condition	Gain	Loss	Mean
1	50·5625	101·6552	101·656	L.H. Matured	50·2248	101·673	101·673	Nightly smalts	0·3323	0·3145	0·3228
2	51·0927				51·1425		0·017				
3	51·5620	103·3125	"	2 . .	51·2485	103·3195	103·3205	"	0·3135	0·3170	0·3152
4	51·7505				52·0710		0·008				
5	50·9040	103·0145	103·0145	3 . .	50·5860	103·0280	103·0290	"	0·3205	0·3180	0·3248
6	52·1105				52·4420		0·0105				
7	51·0015	102·0525	102·0525	R.H. . .	50·6834	102·0630	102·0630	"	0·33·15	0·3181	0·3231
8	51·0510				51·3796		0·0105				
9	50·7693	102·6923	102·6930	Grid cut	51·1135	102·7065	102·7075	"	0·3412	0·3300	0·3371
10	51·9230				51·5930		0·0125				
11	51·5583	102·9340	102·9340	" "	51·9865	103·9473	103·9482	"	0·3282	0·3050	0·3166
12	51·2757				51·2607		0·0125				
13	52·0705	103·8730	103·8730	" "	52·4025	103·8935	103·8950	Heavily smalts	0·3325	0·3120	0·3223
14	51·8030				51·4910		0·0125				

With a current of $\frac{2 \cdot 9}{0 \cdot 014}$ = 59·2 amp. passing for several hours through the meter, the temp. of the air above was 40°C inside. The temp. of the external air being 26°C.
After several hours of 65 amperes this meter. Internal temp. 42°C ext. 25°C.
" " hour of 75 - - - - - 26° - 20°C

27 − 14 = 13 × 0·03 = 0·39 = 0·010039

2700 / 46·0 — 2700 / 2832
27 46 : 2773 :: x : 0·010039 — 5532 :: x : 0·010039

20·5 − 14 = 6·5 × 0·03 = 0·2016 = 0·0100201

2695·5 / 46 — 2695·5 / 2830
27 41·5 — 55258 :: x : 0·0100201

2695·5 / 2830 / 5525·8 :: x : 0·0100201

2695·5 / 5 / 0·5 / 2767·5

27 41·5 — 2767·5

21 − 14 = 7 × 0·03 = 0·21 — 0·10021

2696 / 2818 / 1 / 5515 — 2699 :: 0·10021 : x

Res: of coil in cir. with both 5·10 465·16 + 2 for both = 467·2
" " " " " " 4·12 488·95 + 2 = 494·0
" " " " " " 13·44 492·24 + 2 = 494·4

467·2 / 0·014 = 9334 × 0·3271 = 3214
494·0 / 0·014 = 10023 × 0·3166 = 3173 } 3189
494·4 / 0·014 = 10030 × 0·3170 = 3179
5·06

467·2 + 2·0 = 48·3 / 0·004972 = 9714 × 0·3282 = 3184 } 3115 — 3193 ÷ 1·
467·15 + 2·0 = 48·15 / 0·004972 = 9702 × 0·3170 = 3076
467·055 + 2·0 = 48·06 / 0·004972 = 9664 × 0·3248 = 3189 } 3135
467·165 + 2·0 = 48·165 / 0·004972 = 9667 × 0·3231 = 3130
498
31248

The mean corrected number of amp. hours by standard meter = 3189 gms + 1·2266 = 2666
" " " " " " by left hand strip (Upper) = 2554 × $\frac{1·01}{1·0039}$ = 2568 } 2591
" " " " " " Lower = 2592 × $\frac{1·0039}{1·01}$ = 2623
The mean cor. of both etc has thus been increased in ratio $\frac{2591}{2666}$ = 1·003

Test of Resistance of Meter Bottles.

The test recorded on p. 48 was repeated under more favourable conditions and with less liability to error.

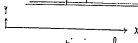
The hot box was maintained at 87°F 30°C and the cold box at 39°F = 4°C. The test commenced at noon on the 23rd Apr. and continued without interruption until 9 am on the 26th (69 hours). The thermostats worked effectively. The current was about $\frac{0.7}{220}$ = 3.3 ampe. (One KHO cell, and 200 v).

Plate	Diff (1-19) 23.5.90	Condition	Shunt	Temp.	Condition on removal	Difference 26.5.90	Thermofor X2	Assumed Thermofor for W2 &c.	W-w	W-w / w	Res. of Shunt	Res. of bottle
1												
2	0.4825	Not analyzed	∞	30°C	slightly smoky	1.3135	0.8310	0.8295				
3	0.8240	"	∞	30°C	o.k.							
4						0.0040	0.8280					
5	1.8530	"	~~0.978~~ 0.978	30°C.		1.5110	0.3420		0.4875	1.426	0.978	1.395
6												
7	0.9540	"	~~2.996~~ 2.996	4°C		1.3555	0.4015		0.4280	1.066	2.992	3.190
8												
9	0.8825	"	~~2.996~~ 2.996	4°C.	slightly smoky	1.2310	0.3485		0.4810	1.380	~~3.016~~ 3.016	4.156
10												
11		"	~~0.986~~ 0.986	30°C								
12	1.9933					2.3175	0.3242		0.5053	1.559	0.993	
13	0.5135	Fold analyzed	~~0.993~~ 0.993	30°C		0.2000	0.3135		0.5160	1.646	0.983	1.618
14												
15		"	~~2.997~~ 2.997	4°C	heavily lightened	0.5325	0.4699		0.3596	0.7653	2.975	2.277
16	1.00224											
17	1.6510	"	~~2.982~~ 2.982	4°C.		2.0655	0.4145		0.4150	1.001	2.980	2.983
18												
19												
20	0.9407	"	∞	4°C	heavy smut	0.1678	0.7729		0.0566	-		
21												
22	0.2585	Black bottle	~~1.996~~ 1.996	4°C	heavy smut	0.1725	0.0860		0.7435	4.310	3.010	12.94

Synopsis of Results

Nos of bottles	Condition		Smut.	Transfer	Shunt	W-w / w	Res. of bottle	Mean	General Mean	Temp			
5-6	Hot Box	Hot	--	0.3420	0.978	1.426	1.395	1.472	1.520	30°			
11-12			—	0.3242	0.993	1.559	1.548						
13-14		Cold	—	0.3135	0.983	1.646	1.618	1.618					
7-8	Cool Box	Hot	—	0.4015	~~2.996~~ 2.992	1.066	~~2.190~~ 3.190	3.673	3.151	4°			
9-10			slight	0.3242	3.0120	1.380	4.156						
15-16		Cold	lightened by smut	0.4699	2.975	0.7653	2.277	2.630					
17-18			"	0.4145	2.980	1.001	2.983						

Elementary Mathematical Theory of relation of permeability of iron to direction of magnetisation.



Let a magnetising force H act in the direction x upon a piece of iron and let this induce a magnetisation I in the same direction, of amount expressed by the equation $I = f(H)$

Then any small increment dH will produce in I an increment

$$dI = d\frac{f(H)}{dH}.dH.$$

The induction $\mathcal{B}$ through the iron will be in the first instance

$$\mathcal{B} = H + 4\pi f(H)$$

and in the second

$$\mathcal{B} + d\mathcal{B} = H + dH + 4\pi\left\{f(H) + d\frac{f(H)}{dH}.dH\right\}$$

and since μ_x is measured by $\frac{d\mathcal{B}}{dH}$

$$\mu_x = \frac{d\mathcal{B}}{dH} = \frac{dH + 4\pi\, d\frac{f(H)}{dH}.dH}{dH} = 1 + 4\pi\, d\frac{f(H)}{dH}.$$

$$= 1 + 4\pi f'(H).$$

Next suppose that a small force h is added in direction y. The resultant will be $\sqrt{(H^2+h^2)} = H + \delta H$ say. The magnetisation in the resultant direction is $I + dI = f(H) + d\frac{f(H)}{dH}.\delta H$ as before, and the resolved part of this in the direction of y is

$$\frac{h}{\sqrt{(H^2+h^2)}}\left\{f(H) + d\frac{f(H)}{dH}\delta H\right\}$$

or $\frac{h}{H}f(H)$ very nearly since h & δH are small.

The induction in direction of y is therefore

$$\mathcal{B}_y = h + 4\pi\frac{h}{H}f(H)$$

$$\text{and } \mu_y = \frac{d\mathcal{B}_y}{dh} = 1 + \frac{4\pi f(H)}{H}$$

Consequently $\mu_x - 1$ should be proportional to $f'(H)$ or $\frac{dI}{dH}$

and $\mu_y - 1$ - - - - $\frac{f(H)}{H}$, or $\frac{I}{H}$, or κ

Also since $I = \frac{(\mu-1)H}{4\pi}$ where μ is a function of H

$$\frac{dI}{dH} = \frac{\mu-1}{4\pi} + \frac{H}{4\pi}\frac{d\mu}{dH}$$

$$\therefore \frac{dI}{dH} - \frac{I}{H} = \frac{H}{4\pi}\frac{d\mu}{dH}$$

So that $\mu_x > \mu_y$ while μ is increasing

$\mu_x = \mu_y$ when μ is a maximum

and $\mu_x < \mu_y$ while μ is diminishing

This relation appears to be fairly well satisfied by the experimental results.

Back of Cylinder I
Time 9.24
Boiler P. 65 lbs.
Mean Imp P 45
Spring 40
Planimeter area 2.185 □"
M.I.P. 20.34 lbs.
[illegible] mm

Back of Cylinder II
Time 9.19
Boiler P. 7 lbs
Mean Imp P 47
Spring 40
Planimeter area 2.17 □"
M.I.P. 20.2 lbs
[illegible] mm

Front of Cylinder III
Time 9.23
Boiler P. 25 lbs
Mean I.P. 51
Spring 30
Planimeter area 2.61 □"
M.I.P. 18.66 lbs
51.5 mm

Front of Cylinder IV
Time 9.15
Boiler P. 67 lbs
Mean I.P. 52.5
Spring 30
Planimeter area 2.44 □"
M.I.P. 18.9 lbs
51.5 mm

Resumé of Results on Copper Matte

No. of Obs.	Date of Trial	Page of Record Book	Amp: hrs passed thro bath	Regulo	Amp: hrs per ton of matte	Weights attached	Mean
1	Mar 19. 1890	12	247	242	684,000	(1)	684,000
2	" 21	13	12	246	492,000	(2)	984,000
3	" "	"	"	313.5	627,000	(1)	627,000
4	" 30th	28	580	216	432,000	(3)	1296,000
5	Apr. 23rd	47.51	600	192	384,000	(3)	1152,000
						10	4743,000
							Mean 474,300

Activity of Brown Engine at Phonograph Works.

29th April 1890.

Engine driving all the machinery and a #10 Dynamo supplying power to the other buildings. The Doll Factory motor however operated from Laboratory direct.

No. of Obs.	Time	Boiler P. lbs	Revs. per min	Diagram	Spring.	Mean I.P. lbs.	Planimeter area	Cut off.	H.P.	Knots.	M.I.P. lbs.	Cylinder
1	9.10	67	51.5	V	40	48	2.25 □"	1.738 1.247	356	26.6	20.5	Back
2	9.15	67	"	III	30	52.5	2.64	1.695 1.265	32.03	23.9	18.9	Front
3	9.16	"	"	II	40	47	2.17	1.738 1.247	35.1	26.2	20.2	Back
4	9.23	65	"	III	30	51	2.61	1.695 1.265	31.62	23.6	18.66	Front
5	9.24	"	"	I	40	45	2.185	1.738 1.247	35.25	26.3	20.28	Back
									134.00	100.0		
									67.00	50.0		

Measurement of Platinoid Governor Shunt Wire for Phonograph Factory 29th April 1890.

The resistance of this shunt wire has always been 1 ω.
A sample of wire was tested. Diam 0.0185". Length 17½" = 1 ω.
27" of this wire is little more than 1.5 ω.

Smutting tests of meter bottles.

Four bottles standard new type made up two with hot and two with cold amalgam. Temp. of room about 18° C. Circuit closed at 17 o'clock I. V. 90. Smut discovered 8 o'clock I. V. 90. or after 15 hours. Current 16 milliamperes or approximately double full load. No appreciable difference in behavior between the hot and cold amalgamations. It is probable that smutting commenced after 12 hours, and commenced at the edges of the plates.

Ten meter bottles in proper condition with new plates were emptied into a cylinder. The total volume amounted to 314.8 c.c. or 35 c.c. per bottle.

Smutting of the plates in the 8 mamp + 12 mamp bottles commenced to be visible after about 9 hours in each case.

Electro-Deposition of Matte.

The last experiment on deposition of matte recorded on page 47 was continued with about 8 amperes of current until the 6th May. The matte plate was then weighed and the results compared.

Loss of Copper bath anode 244 g) = 680.4
Gain - - - cathode 243 g. = 673.4 } Mean 676.9
Loss of Matte 3 lbs = 1360.8
Ratio of matte loss to copper loss 2.01

384 1 amp. hr. dissolves 1 lb. of copper
1 g. - - - 1 - matte
384,000 - - - 1 ton of matte.

46·46 (1 + 0·00388 × 11) 46·46 (1 − 0·00388 × 11) 46·46 (1 + 0·00 0088)

46·46 × 0·99 8728 = 46·29 46·46 × 0·99 8728 = 46·41 46·46 × 1·03 445

As shown at the foot of the opposite page, the best mean value for the bottle resistance is

1·80 @ 30°C
2·5 @ 24°C
4·10 @ 10°C

The resistance of the steel being 46·46 ω @ 21·1°C. = 46·29 ω @ 20°C
46·46 ω @ 10°C
48·07 ω @ 30°C

@ 10°C, the bottle circuit is 48·58 ω 0·47 in defect or nearly 1%
@ 30°C . . . 49·87 ω 0·9 in excess or nearly 2%
@ 21·1°C . . . 48·96 ω

x (0·95725) = 1·6 x × 0·0345 = 0·7
0·04231 x = 1·6 x = 20·3 Ω
x = 37·9 Ω } 9·36 9·5 26·16
46·46 ω 46·46

Test of the Resistance of Meter Bottles.

The test recorded on p. 49 was repeated. The hot box temperature could not be sustained however, and its probable mean temperature was about 21°C. The cold box temperature was steady at 4°. The current was about 3·5 m amps through series. Amalgam all cold. Fuels Laboratory solution 3% zinc.

Day	Bottle	Shunt	Temp.	Condition on removal	Difference	Difference	Transfer ×2	Assumed Transfer for bottle	W − w	W/w	Res. of bottle	(W − w)/w	Mean res.
1		#1.2-9.40	Bot 10°C	OK.	1·3245	2·1160	0·7935		0·5900	1·345	2·487	0·7495	
2												0·7495	
3		#2-2.97	"	"	0·4885	1·2615	0·7730		0·6105	1·266	2·364	0·7698	
4													
5		#3-2.98	"	"	0·3475	1·2195	0·7720		0·6115	1·263	2·360	0·7919	2·359 @ 4°?
6													
7		#4-3.00	"	"	0·3460	1·1070	0·7610		0·6225	1·222	2·265	0·8183	
8													
9		#5-2.97	"	"	0·3015	1·0790	0·7775		0·6060	1·283	2·319	0·7794	
10													
11		#7-0.94	Hot 20°?	"	0·2325	0·7340	0·5015		0·8820	0·5685	1·750	1·759	
12													
13		#8-0.98	"	"	0·6775	1·1435	0·4660		0·9175	0·5079	1·936	1·969	
14													
15		#9-1.02	"	"	0·4175	0·7910	0·3735		1·0100	?	-	—	1·887 @ 24°C ?
16													
17		#10-0.98	"	"	0·3220	0·7860	0·4640		0·9195	0·5046	1·968	1·982	
18													
19	∞		"	"	0·0420	1·4260	1·3840						
20													
21	∞		"	"	0·2230	1·6010	1·3780	1·3835					
22													
23	∞		Bot. 10°C	Bottle Shunted	1·3205	0·0660	1·3885						
24													

Collection of Results on Bottle Resistance.

(1)	Mary 6½ 1889	Record Book III p. 107	Calorimetry Test	Bottle after use =	1·04 ω @ 32°C	3·76 @ 4·5°C		
(2)	" 14th "	" " " 109	" "	" " "	0·72 @ 34·5°C	3·16 @ 10·3°C		
(3)	" 22nd "	" " " 124	" "	" " temp	1·27 @ 31·4	7·87 @ 6·5°C		
(4)	June 8th "	" " " 138	" "	" " temp	1·46 @ 32·2	5·07 @ 7·7		
(5)	" 11th "	" " "	Pattison Test	bottle ground	2·52 ω @ 20°C.			
(6)	" 29th "	" " "	Laboratory	" "	2·635 @ 23·3°C.			
(7)	" " "	" " "	"	" "	1·74 ω @ 32·2	4·07 @ 8·3	2·45 ω	
(8)	April 18th 1890	" " III " 49	"	" " temp bottle shunted	1·52 @ 30°	3·15 @ 4°		
(9)	" 30th "	" " " 52	"	" "	2·36 @ 4°C.			

Best results are No. 4 1·46 ω @ 32·2 5·07 @ 7·7 = 3·61 ω for 24·5° = 2·85
" 7 1·74 " " 4·07 @ 8·3 = 2·33 ω " 23·9° = 1·95
" 8 1·52 " 30° 3·15 @ 4° = 1·73 ω " 26° = 1·67
0·66

Referring these to 30°, 10°. No 4 = 1·69 @ 30° 4·83 @ 10°C Weight (3)
7 1·97 " " 3·89 " " (3)
8 1·52 " " 2·53 " " (1)

5·07 " 30° 14·49
5·91 11·69
1·52 2·53
12·50 28·49
1·79 4·10

Tests to ascertain the amount of local action in the Edison-Lalande battery. 5th May 1890.

Weights were taken of 15 zincs of the small telephone type. All these zincs were put into cells, and the cells left idle on open circuit. The object of the test was to see how the method of uniting the zincs and coppers affected the local action in the cell. Three Nos. 1 + 3 were connected with the usual silver-latex rubber connector. Three others Nos. 5 & 6 were connected with rubber connector of the smooth metal pattern from Bergmann & Co. Three nos 2 + 4 were connected above by V washers of rubber pointing downwards, Two, nos 7 + 8 were not connected at all but were kept apart widely from the coppers, and the remaining four nos 10. 12. 14. 15 were cast in one bottle touching each other without any coppers.

Zinc No.	Weight 5.V.90	Connection	Weight 8.V.90	Loss	Weight 11.V.90	Loss	Weight 19.V.90	Weight 26.V.90	Loss				
1	32.685	Ordinary	32.525	0.160	32.330	0.355		31.910	0.775				
2	34.865	Polished ▼	34.815	0.050	33.910	0.955		26.495	8.370				
3	32.960	Ordinary	32.920	0.040	32.865	0.095		15.005	17.955				
4	34.480	Polished ▼	34.435	0.045	34.345	0.135		broken 30.030	30.				
5	31.390	Polished ●	31.355	0.035	31.300	0.090		30.030	1.360				
6	31.720	Polished ●	31.670	0.050	31.570	0.150		23.840	7.920				
7	28.185	no connection	28.005	0.180	25.180	3.005	24.737	22.440	4.745				
8	32.695	" "	32.670	0.025	32.625	0.070	Box of 24.3 removed the Nos + left in box in solution of Nitric Acid	32.260	0.435				
9	31.320	Polished ▲	31.270	0.050	30.910	0.410		29.080	2.240				
10	35.270	Alone	35.245	0.025	35.210	0.060		35.075	0.195				
11	29.085												
12	34.090	Alone	34.055	0.035	34.055	0.035		33.980	0.110				
13	33.490		33.485	0.005	33.470	0.020		33.385	0.105				
14	31.460	Alone	31.435	0.025	31.420	0.040		31.230	0.230				
15	33.185	Alone											
16													

To check the experiment in progress as recorded on p. 40. concerning the loss by local action of plates in Nitric Acid, four cells were made up just under practical working conditions, but left on open circuit, with the zincs weighed as follows:-

Zinc No.	Weight 6.8.90	Weight Wt. 6.V.90	Weight Wt. 10.V.90	Weight Wt. 11.V.90	Weight Wt. 28.V.90								
10	5142.5	3333	337.1	330.5	32.9								
11	5187.5	336.2	340.3	335.7	331.2								
12	5052.5	327.4	324.9	299.6	301.5								
13	5012.5	324.9	330.6	328.0	327								
14	12280	12,495	12545	12472	12498.8								
15	12031	12,335	12405	12332	12398								
16	12052	12,352	12405	12356	12401.3								
17	12962	12,290	12314	12294	12348								
	Mean	330.5	328.2	323.14	322.2								
	"	12364.8	12402.14	12364.14	12400.9								

11g 333
" 375.
" 240
" 200
24h 12g 34
11g 284
11g 250
11g 150.

Test commenced 6th May. Copper oxide plates in each jar.
Sp. g. of solution 1.280

Meteorological Record.

Date	Time	Barometer readings Inches.	Bend.	Temp.	Degrees of F.C.	Thermometer readings Max.	Min.	Dry	Wet	Rainfall in Inches.	Wind	Remarks.
May 3	Noon	29.562	75.87	67°	29.736	62°	39°	60°			SE	Fair
4		29.551	75.11	63°	29.466	63	42	60				Overcast
5		29.347	74.60	66°	29.267	74	58	73		.34	S	Raining
6		29.489	74.67	66°	29.341	75	60	59	58	.34	N.W.	Rainy
7		29.125	75.60	61°	29.636	65	45	59	51	.06	W	Overcast Raing.
8		29.724	75.78	69°	29.618	63	44	46	44	.08	N.W.	Raining.
9		29.571	75.88	65°	29.112	68	44	60	63		S	Fair.
10		29.677	75.39	63°	29.394	70	56	67	62		N	Overcast
11		29.567	75.87	62°	29.771	72	50	57	52	.065	W.	Raining.
12		29.869	75.82	62°	29.259	71	45	61	54		SE	Fair.
13		29.617	75.23	63°	29.534	72	46	63	59		E	Overcast
14		29.529	75.02	69°	29.419	72	59	75	69	.415	S	Overcast, Fair
15		29.435	74.20	60°	29.527	78	63	65	63	.51	SW.	Raining.
16		29.645	75.31	60°	29.537	85	56	73	65	.01	SW.	Overcast. Fair
17		29.655	75.33	63°	29.562	78°	44°	63°	55°	.17	S	Overcast
18		29.663	75.57	62°	29.733	74°	43°	61°	55°			Fair.
19		29.673	75.43	63°	29.400	70°	50°	60°	65°		E	Overcast
20		29.323	74.64	66°	29.291	71°	52°	60°	57°	.43	N.W.	Raining
21		29.771	76.10	62°	29.581	70°	43°	61°	56°	.04	N	Fair.
22		29.770	76.27	63°	29.815	69°	43°	61°	56°		N.E	Fair.
23		29.853	75.91	62	29.783	69	42	60	56		N.W.	Fair.
24		29.815	75.70	64°	29.728	70	56	68	64		N.E	Fair Overcast
25												
26		29.269	75.83	67°	29.162	72°	52°	50°	50°	.24	E	Raining
27		29.563	75.10	69°	29.467	71	59	71	67	.9	NW	Overcast
28		29.663	75.39	65°	29.568	76	53	63	59		W	Fair
29		29.777	75.64	67°	29.672	78	53	68	62		N.W.	Fair
30		29.696	75.43	67°	29.590	77°	52°	67°	64°		E	Fair Overcast
31		29.682	75.18	68°	29.474	80°	50°	72°	66°		W.	Fair
June 1		29.703	75.46	71°	29.531	88°	53°	76°	70°			Fair
2		29.717	75.74	73°	29.656	80°	55°	76°	67°		N.W.	Fair
3		29.725	76.02	70°	29.811	81°	58°	72°	66°		E.	Overcast
4												
5												
6		29.685	75.41	78	29.547	80°	63°	80°	73	.375	NE	Fair
7		29.641	75.30	76°	29.515	83	62°	77°	65°	.33	SW.	Fair Overcast
8												
9		30.087	76.23	72°	29.819	82°	54°	75°	70°		S.	Fair
10												
11												
12		29.645	75.32	76°	29.523	86°	56°	75°	72°	.80	E	Raining.
13		29.665	75.35	68°	29.557	77°	55°	66°	65°	.19	N	Overcast
14		29.667	75.37	70	29.555	79	62	68	67	.38	N	Overcast
15		29.869	75.86	70	29.765	75	62	67	65	.25		Rain Overcast
16												
17		29.891	75.85	67°	29.760	78	52	71	69		SE	Overcast
18		29.644	75.27	70	29.530	86	53	83	80		S	Overcast
19		29.703	75.91	77°	29.568	87°	53°	79°	74°		N.W.	Fair
20		29.935	76.04	76°	29.801	83°	52°	71°	66		N	Fair
21		29.535	75.53	70°	29.739	73°	55°	63°	62°	.10	SE	Overcast Rain
22		29.701	75.45	67°	29.674	73°	56°	71	67	1.01	N.W.	Overcast Fair
23		29.567	75.84	68°	29.759	78°	62°	67°	65°		N	Overcast
24		29.805	75.71	72°	29.683	83	65	79	73	.015	N.W.	Fair.
25		29.577	75.14	84	29.471	87	73	83	79		N.W	Fair
26		29.637	75.57	80°	29.493	90°	68°	80°	74°		N.W.	Fair
27		29.688	75.31	75°	29.518	83°	62°	72°	68°		N.W.	Fair
28		29.609	75.21	76°	29.483	81°	62°	76°	73°		SW.	Fair Overcast
29		29.644	75.21	77°		89	65	79	74		N.	
30		29.729	75.52	77°	29.491	93°	67°	82°	77°		N.W.	Fair
July 1		29.761	75.64	80°	29.617	93°	63°	87°	77°		SE	Fair Overcast
2		29.679	75.44	75°	29.570	89	66	74	71	.35	SE	Overcast Raing
3												
4		29.534	75.15	73		79	70	77	75	.37	S.W.	Rain

Meter Experiment 8th May. 1890

Since the electro chemical equivalent of Bismuth is 2·184 mgms, and that of Zinc is 0·337, it follows that Bismuth would be six times as valuable as zinc in a meter designed to absorb very little power. Made up solutions of 5 grammes of Bismuth in Hydrochloric sulphate, oxychloride, iodide, nitrate, subnitrate, oxyhydrate, ~~and~~ subcarbonate and phosphate. All these salts appear to be practically insoluble in water. Tried the nitrate with nitric acid. This rendered it soluble but the strength of acid which did so attacked free bismuth plunged in it. Tried the sulphate in sulphuric acid with more success. This dissolved the salt and at the same time did not apparently attack the plate. The resistance of a little cell made up in this way with small pieces of bismuth, not exposing more than 0.5 sq. cm. each was 10 ω f.e. 50 ~ 12 ~~volts~~ ~~in~~ 100 ohms or 3 milliampere = 40 × 0·003 = 0.12 volt counter e.m.f. This is comparatively good.

Test of the Wint Lightning Protector. 9th May. 1890

This apparatus consists of a grounded base plate and frame holding a vertical column of 20 copper washers separated by disks of mica. Each washer is 0·3 thick and 5. in diam. The mica disks are about 0·08 thick. An insulated wire runs through these washers to the top one with which it makes permanent connection. The effect of the plates is to permit the discharge of high tensions without allowing the municipal current to follow it.

Two protectors were received for test. Number one was tested with the municipal dynamo for simple resistance to disruption. With about 900 volts the machine could only be got to discharge at the last plate. With six leyden jars each exposing about 1·5 sq. ft. or nearly 10 sq. ft. of glass in all and the Holtz machine, a spark of about ¾" could be obtained, very dense and with a loud report. With 600 volts at the dynamo, the leyden jar discharge did not precipitate the discharge of the machine over 2 plates but 1000 volts were precipitated. With the leyden jars, the discharge would take place across all twenty plates.

Number two was tested in the same way. The machine would not discharge across three plates until the PD was raised to about 1000 volts.

Since a 300 amp. hr. cell holds 0.7 gallon of solution

burns	3·6 lbs of zinc	per cell
reduces	1 - -	CuO - -
consumes	2 - -	$NaHO$ - -

the 3000 amp. hr. cell will need 7 gallons of solution

36 lbs. of zinc

10 - - CuO

20 - - $NaHO$

Suppose that we take 7 gallons of solution

46 lbs of zinc

10 - - CuO

20 - - $NaHO$.

1 gallon U.S. = 270 c.i. 1890 c.i. required

If 12" in diam. internally - 113 sq. in. area

= 16.7" high.

Say 12" diam. and 20" high.

Two zinc plates 9" × 19" each ·225 lbs wt

171 sq. in. = 42 lbs. if 1" thick

Four zinc plates 9" × 19" × ½"

In the 300 amp. hr. cell a CuO plate 4·75" × 4" × 0.375" = 7.125 cu. in. weighs 1 lb. 19 sq. in.

Two plates 15" high × 6⅓" wide 95 sq. in. each 5 lbs.

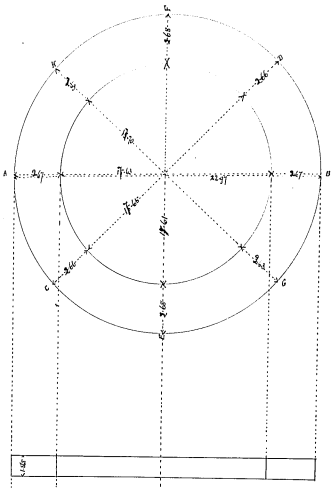
The 900 amp. hr. cell holds 2·5 gallons, without allowance for lift out. 11½" high to shoulder. 7½" diam.

Comparison between the Cost of Operating a Mason-Reed Battery, and an Edison-Lalande Battery, for current, and for power.

		Mason.	Edison-Lalande
Dimensions	Area occupied per cell	100 sq. in.	244 sq. in
	Height - - -	12"	12"
	Weight charged - -	60 lbs.	18½ lbs.
	Floor space per actually occupied H.P. (@ 4 amperes)	70 sq. ft	37 sq. ft.
	Weight per H.P. (@ 4 amperes)	6000 lbs.	5550 lbs.
	Cost to purchaser per cell	$ 7.20	$ 2.25
	- - - per H.P.	$ 720	$ 675
	Ampère hours at 4 amperes	180	290
	Initial E.M.F. per cell	2·2 volts	0·8 volt
	Mean - - -	2·0 -	0·7 -
	Mean int. res. - -	0·08 ohms	0·03 ohms
	Mean P.D. - -	1·45 volts	0·57 volt.
	Mean ch. energy per cell @ 4·5	7·5 Watts.	2·5 Watts
	Mean cells per H.P. est.	100	300.
	Zinc consumed per 1000 H.P. hr.	12.13 lbs.	36.40 lbs.
	Cost of Zinc consumed per 1000 H.P. hr.	$ 97	$ 291
	Charge of Depolarizing fluid p.c. (1820)	½ gallon	
	Depolarizing fluid per amp. hr. per cell	0.003 gallon.	
	- - - H.P. hr.	0.8 -	
	- - - 1000 H.P. hr.	800	
	Depolarizing consumed of Depolarizer per gallon	$ 0.25	
	- - - - - H.P. hr.		$ 0.075
	- - - - - 1000 H.P. hr.		$ 75
	Sulphuric acid per amp. hr. per cell	0·008 lb.	
	- - - H.P. hr.	1 lb.	$ 0.0125
	- - - 1000 H.P. hr.	1000 lbs. @ $0.0125	$ 12.50
	Copper-oxide consumed per amp. hr. per cell	0·0033 lbs.	
	- - - - H.P. -	1 lb.	
	- - - - 1000 H.P. -	1000 lbs.	
	Cost of copper-oxide per 1000 H.P. hr. allowing for copper as 20 cts. lb	$ 200	
	Caustic Soda consumed per amp. hr. per cell	0·008 lbs	
	- - - - H.P. hr.	2 lbs.	
	- - - - 1000 H.P. hrs.	2000 lbs.	
	Cost of caustic soda per 1000 H.P. hrs. @ 8 cts. lb.	$ 160.	

Total cost of Mason cell per 1000 H.P. hrs. $ 187 = $ 0·19 per H.P. hr.

" " " Edison-Lalande - - - - - $ 790 = $ 0·79 per H.P. hr.



$22.96 + 17.65 = 40.61 = 20.303 \times 3.1416 = 62.96 \times \frac{5}{11} = 167.15 \times 1.565 = 261.6$

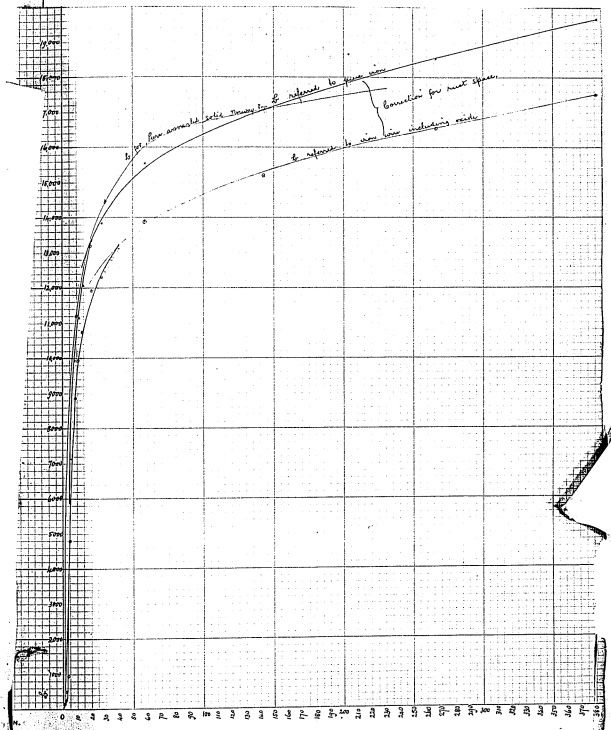
Area of iron + ends $= 11.38 \times 0.018 \times 0.018 \times 6.4516 \times 0.7854 = 2.361$ sq. inch

Source of EMF	Temp	Resds.	EMF at temp	a	No. of turns	Mean Thur	t_m	a per sec
1 Ch.	20.5°C	1 ρ 1×10^{-15}	1.4322×10^{-3}	1.4322×10^{-3}	13	121.5	± 0.1	1.179×10^{-3}
1 Ch.	20°C	1 ρ	1.4325	1.4325	14	124.7	± 0.15	1.149×10^{-3}

$\rho = d \times 1.179 \times 10^{-3} \times 7 \times 10^{3} \div 10^{2} = dr \times 1.179 \times \frac{7}{100}$

$+ \; d \times 1.149 \times 10^{-3} \times 7 \times 10^{3} \div 10^{2} = dr \times 1.149 \times \frac{7}{100}$

On dropping these pieces of rusted iron the iron diam. were found to average 0.017" and over rust 0.018 so the area has been reduced in ratio 289 : 324 ∴ the observed values of L may be multiplied by $\frac{324}{289} = 1.121$


Is the flow assumed to be stream line to be referred to free surface
Correction for mean spheres
Is referred to mean line indicating reality

H C.G.S.U.

Magnetic Permeability of an Iron Wire Ring from Schenectady) compressed hydraulically)

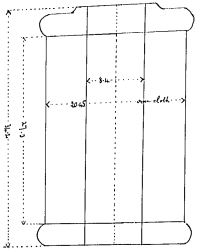
This ring was received from Schenectady on the evening of the 11th May. It was made up of 11.38 turns of #26 BWG 0.018" 0.045cm. oxydized superficially. Its breadth was about 45 wire (per layer) and its depth about 32. This would represent 16.9 wire per cm. in breadth and 20.125 wire per cm. in depth.
0.059 cm. each — 0.0749 cm. each

Ext. Diam.	Mean Ext. Diam.	Probable error.	Int. Diam.	Mean Int. Diam.	Probable error.	Depth	Mean Depth.	Probable error.	Surface area.	Volume.	Cross section Mean.	Weight in air.	Sp. g.
22.97			17.63			1.52							
						1.56							
22.96						1.52							
	22.96	±0.003	17.65	17.65	±0.01	1.59	1.565	±0.011	167.4	2626	4.155	1189.6	4.5
22.97	See Index 22.89					1.60							
			17.61	See Index 16.95		1.60	See Index 1.495						
				17.72		1.60				2433	3.865 allowing for Lap.		4.5
22.95						1.53							
			17.70										

Mean Diam. 20.205 Mean Circumference 62.96 Sp.g. refund to the wire 8.00.

50 turns of #25 BWG. copper wire were laged on in one layer upon the ring over tape. Above this 231 turns of 0.072" covered to 0.086" in one layer, there 231 similar turns in a second layer, and 227 similar turns again in a third layer. The total no. of turns being 689, or 10.94 per cm.
13.721

Flux in Webers	Sol. Cotan. Deflection	Time of Dep.	Current amperes	H	No. of Shunts.	Mean Throw	Probable error.	φ (6.199)	Resist. in G. coil.	L refund to Ferrite.	μ.	L refund to the wire only.
21+50	6°.35'	0.1154	0.087	1.194	5	5.9	±0.1	365.3	5,250	155		174
31+50	9°.30'	0.1673	0.126	1.729	6	6.9	±0.2	551	"	233		261
21+110	13°.15'	0.2355	0.1775	2.436	4	17.1	±0.4	1059	"	448.5		503
21+50	15°.15'	0.2726	0.2055	2.820	7	22.7	±0.5	1405	"	595		667
21	16°.15'	0.2915	0.2198	3.016	8	36.2	±0.6	2241	"	949.2		1064
	17°.25'	0.3201	0.2414	3.313	4	50.7	±0.5	3139	"	1330.		1491
	19°.15'	0.3492	0.2633	3.614	5	72.8	±0.4	4507	"	1909		2140
	21°.0	0.3839	0.2895	3.973	5	103.4	±0.7	6400	"	2711		3039
	22°.40'	0.4176 0.063	0.3144 0.3183	4.321 4.367	6	134.8	±0.7	8344	"	3534		3969
		0.070	0.3536	4.854	6	183.3	±1.4	11350	"	4808		5390
41+110	6°.15'	0.1695	0.073	1.139	4	9.3	±0.8	561	"	238		267
31+110	9°.5'	0.1599	0.121	1.661	5	14.4	±0.7	869	"	368		412
21+110	12°.0	0.2493	0.188	2.580	6	37.3	±0.7	2250	"	953		1068
21	17°.30	0.3123 0.0149	0.2371 0.2478	3.259 3.397	5	76.7	±0.6	4627	"	1960		2197
11+{1/2}		0.053	0.268	3.678	6	99.7	±0.9	6015	"	2546		2856
11+110		0.061	0.308	4.227	5	138.8	±0.7	8372	"	3547		3976
11+40		0.078	0.394	5.407	5	207.2	±0.8	12,500	"	5295		5935
11+10		0.090	0.455	6.245	5	244.0 244.0	±1.6 ±1.0	14,800 15,300	3,250	6374		7144
{1/2}+70		0.110	0.556	7.632	6	52.5	±0.4	18,250	"	7730		8664
{1/2}+29		0.134	0.678	9.306	6	60.2	±0.1	20,930	"	8866		9940
{1/2}+19		0.170	0.8565	11.780	5	67.5	±0.4	23,460	"	9936		11,140
{1/2}		0.205	1.035	14.21	6	73.1	±0.3	25,410	"	10,760		12,060
72		0.302	1.526	20.94	5	81	±1.1	28,150	"	11,920		13,360
		0.441	2.025	27.79	4	96 162.3	±1.1	29,890 28,370	7,250 16,250	12,330		13,820
		0.855	4.32	59.29	5	187.2	±1.5	32,790	"	13,890		15,570
		2.05	10.35	142.1	4	204.8	±2.4	35,880	"	15,200		17,040
		3.84	19.4	266.3	4	223	±0.5	39,070	"	16,550		18,550
		5.60	27.78	381.3	3	236.3	±0.7	41,390	"	17,530		19,650



Section of coil 1/10

Weight of coil complete 11 kg.

Inductance of the large Secondary Coil of the Queen Ruhmkorff apparatus.

16th May 1890.

This coil on a wooden frame is separate and lifts off the machine. With a view to its employment in radiant experiments, measured its inductance as follows:-

T.B.	Ratio of Bridge.	Corrected Ratio	Res. for Balance	Corrected L T.B.	Temp. of coil.	Capacity for 1 mf.	Inductance Standard	Time Const. corrected	Time Const. of coil to 0°C.				
22·3	10,000 / 10,000	9.9,120 / 10,000	15,910	20·1 C.	20·4°C	0·701	1095	8,8070	15,666	see also Book III p. 15.			

The total weight is 24·½ lb. Supposing that 2D of this is wire, the res. per lb is 780 ω. This means either #33 BWG 0·008" 832 ω per lb. or #32 B.S. 0·007 95" ·853 ω per lb. These have about 6·16 ft per ohm. or 15600 × 6·16 = 96,120 feet in all. The mean diam is 14·42 cm = $\frac{14 \cdot 42}{30 \cdot 48} \times 3 \cdot 14 = 1 \cdot 486'$ per turn, there will thus be some 64,700. turns of wire.

Experiments with a Cautery Battery of 10 cells.

16th May 1890.

Three cauteries were tested. They were received from Mr Kelly as samples of the requirements to be fulfilled by the battery. A hard rubber handle or stock holds each cautery in a pair of small screw-side terminals. The connections from the wires run through the handle which has a little connecting key at the side for closing the circuit by the finger, and terminate in two large conical nickel plated studs for insertion in the main leads.

The wire cautery consists of a loop of platinum wire 0·017" (0·043) in diam which passes through two copper tubes or hollow guide wires locked together. These tubes enlarge in diameter from the cautery (0·085") up to the clamping end (0·115"). The platinum wire runs entirely through these tubes and is bound round the axis of a little hard rubber roller held by two nickel plated arms about 2·5 long pivoted into the handle. The thumb of the operator can thus diminish the length of the loop by drawing the roller and its attached wire through the tubes. The loop can be thus reduced from 20 to 2 cms.

The knife cautery consists of a pair of stout stems terminating in a little loop of flattened platinum wire. The blade is 0·025 ω thick and about 0·1 cm. wide ⊕ shape. The effective length being about 2 cms.

No. of Exp.	Length of Pt. cautery	Condition	Colour	Current	PD. on Cautery	Res. of cautery	Res. per cm.	Length of wire in cell.	res. of wire	Nat. cells
1	19	Glowing red	1·5	7·6	5·9	0·776 ω	0·0461 ω	40 mm Res. 0·08	0·34	19.
2	10	Nearly white	1·62	8·2	3·65	0·4455 ω	0·0445 ω	65..	0·55	19
3	Knife	- -	3·70	18·7	less than 15	–	–	none	–	10
4	–	Glowing red	3·60	18·2	- - -	-	-	-	-	8
5	Min 15·0	Nearly white	1·46	7·4	4·65	0·628	0·0420 ω			10
6	3	" "	"	"	"			30	0·25 ω	10.
7	none	out of cell	5·60	28·3						10 cells 7·8 ω
	Res. of battery	+ leads	0·275 ω	=		0·25 ω for battery per cell.		+ 0·015 ω for lead		+ 9.

Calibration of Obach Ring Galvanometer

17th May 1889.

At commencement of the measurement, silver plate A was found to be heavier than silver plate B 1.9190 gms.

The current of about 2·6 amperes was passed through the Galvanometer and silver Voltameter in series for 300 seconds.

The mean of all the readings of the galvanometer tangents taken every 15 seconds was 0·5270

The plate A after drying was then found to be heavier than B 0·1028 -

Double transfer 1·8162.

Transfer 0·9081.

In one second the transfer would be 0.0030270 gms.

3·027 ÷ 1·118 = 2·707 amperes = 5.137 for tangent unity

= 0·1947 for 1 ampere.

Experiment on the action of Lithium Chloride upon Uric acid.

20th May 1890.

A few centigrammes of ~~Lithic~~ Uric acid $H_2C_5N_4O_3$ were shaken up with about 2 c.c. of distilled H_2O in a small test tube, and about 2 c.c. of liquid Lithium chloride $LiCl$ added. The two were neutral before mixing, and the mixture was also neutral, showing that no free HCl was found. A rise of temperature was however detected in the test tube.

Repeated the experiment as follows:— about 2 c.c. of $LiCl$ at 19·C was added in a similar test tube to some dry powdered Uric acid. The mixture was stirred by the thermometer bulb and rose to 22·C. very quickly and then slowly fell.

On adding strong HNO_3 to the mixture and evaporating in a sand bath, distinct fumes of ammonia were detected. When however HNO_3 was added to the uric acid alone, no ammonia could be detected by smell and heated. ~~Although~~ a finished deposit turning purple on the addition of KHO showed that there was some small quantity present.

It is therefore probable that the addition of $LiCl$ to uric acid produces some combination but no such reaction as would liberate the chlorine; or form HCl.

Phonographic Battery data

The ordinary 300 amp. hr. New HO battery takes 2750 c.c. of solution Sp. g. 1.25 - 1.26 to fill it, and 2 lbs of NaHO 907 gms.

The rectangular section cell for cautery purposes takes 1500 cc and at the same rate 1 lb. 1 g.

Test of a number of Fuse plug cut outs for Bergmann & Co.

May 23rd 24th

40 cut outs were received from Messrs Bergmann & Co. for test. They were marked from 18 24 30 and 37 ten of each kind. They were not filled with plaster of paris as has hitherto been customary, and the object of the test was to ascertain how far this would be a benefit or disadvantage.

Arranged a plug socket in direct circuit with the Obach Galvanometer, a table wire resistance for controlling the current and the 5 volt main, employing the potentiometer on the socket to measure the p.d. on the tested plug.

No. of Obs.	Number on plug.	Condition	Obach	amperes	P.D. volts	Energy in plug	Res. of plug	Ratio of Res.	Ratio of energy based on 1·00	Diameter of wire
1	37	no plaster	1·17	5·94	0·0744	0·26	0·0074	1·		0·0089"
2			1·68	8·53	0·076		0·0089			
3			2·0	10·15	0·112		0·0110			
4			2·25	11·42	0·104		0·0091			
5		3 used.	2·60	13·20	0·168	2·22	0·0127	1·72	1·81	0·023 cm
1	37	no plaster	1·42	7·20	0·066	0·61	0·00944			
2			2·46	10·97	0·104		0·0095			
3			2·48	12·59	0·196	2·47	0·0156	1·70	2·23	
1	37	no plaster	1·42	7·21	0·062		0·0086			
2			2·48	12·79	0·192	2·46	0·0150	1·74	2·14	
1	37	no plaster	1·47	7·46	0·072		0·0096			
2			2·40	12·18	0·196	2·39	0·0160	1·68	2·3	
1	37	no plaster (paraffin wax used when remoulded)	1·44	7·31	0·060		0·0082			
2			2·56	13·00	0·198	2·59	0·0152		2·17	
1	37	Cup half filled with water	1·40	7·11	0·062		0·0087			
2			2·50	14·21	0·204	2·81	0·0144		2·06	
1	37	cup dry	1·40	7·11	0·058		0·0082			
2			2·58	13·1	0·258	3·38	0·0197		2·81	
1	37	plaster	1·46	7·41	0·060		0·0081			
2			4·40	22·33	0·210	4·68	0·0094		1·33	
1	37		1·53	7·76	0·060		0·0077			
2			4·40	22·33	0·250	5·58	0·0112		1·60	
1	37		1·50	7·61	0·060		0·0079			
2			4·40	22·33	0·200		0·0090			
3			4·70	23·86	0·250	5·97	0·0147		1·50	
1	30	no plaster, dry.	1·52	7·71	0·080		0·0102			0·007"
2			2·22	11·27	0·200	2·25	0·0178			0·0177 cm
1	30	no plaster, dry.	1·54	7·81	0·072		0·0092			
2			2·32	11·78	0·200	2·35	0·0170			
1	30	no plaster, cover removed, dry.	1·50	7·61	0·076		0·010			
2			2·16	10·97	0·200	2·19	0·0182			
1	30	no plaster, cover on, dry.	1·54	7·82	0·080		0·010			
2			1·68	8·53	0·088		0·010			
3			1·86	9·44	0·102		0·0108			
4			1·96	9·95	0·112		0·0113			
5			2·07	10·51	0·122		0·0116			
6			2·16	10·96	0·138		0·0126			
7			2·24	11·37	0·204	2·27	0·0179			

Plate	Number in plating	Condition	Ohms	Amperes	P.D. volts	Energy in plating	Res. of plating	Ratio of res.	Diam. of wire		
1	30	dry, no plate cover on	1·48	7·59	0·066						
2			1·60		0·074						
3			1·82		0·086						
4			1·96		0·098						
5			2·05		0·104						
6			2·126	10·90	0·112						
7			2·200	11·28	0·120						
8			2·240	11·49	0·210	2·41					
1	30	dry, no plate	1·50	7·69	0·074						
2		vertical	1·66		0·086						
3		cover on	1·82		0·096						
4			2·02		0·114						
5			2·12	10·87	0·128						
6			2·16	11·08	0·134						
7			2·20	12·88	0·360	4·64					
1	30	dry, no plates	1·48	7·59	0·100						
2			1·60		0·110						
3			1·72		0·118						
4			1·92		0·126						
5			1·94		0·136						
6			2·02		0·142						
7			2·06		0·144						
8			2·10		0·150						
9			2·16		0·156						
10			2·20	11·30	0·160						
11			2·26	11·60	0·166						
12			2·28	11·70	0·172						
13			2·32	11·90	0·180						
					0·360	3·09					
1	30	dry plates	1·48	7·59	0·074						
2			1·70		0·086						
3			1·78		0·092						
4			1·90		0·100						
5			2·00		0·108						
6			2·18		0·122						
7			2·28		0·130						
8			2·36		0·146						
9			2·56		0·300						
10			2·60	13·34	0·360						
11			2·72	13·95	0·400						
12			2·80	14·36	0·460						
13			2·96	15·18	0·580	8·80					
1	30	plates dry	1·48	7·59	0·070						
2			2·60	13·33	0·310	4·13					
1	30	plates dry	1·48	7·59	0·080						
2			2·40	12·31	0·300	3·69					

Test No.	Number on plug	Condition	Obsch.	Amperes	P.D. Volts	Energy in plug	Res. of plug	Ratio of Res.	Diam. of lead wire	
1	24 lt	Dry no plastic	1·16	5·95	0·106		0·0178			
2			–		0·220					
1	24 lt	no plastic	1·26	6·46	0·118		0·0183			
2			1·40	7·18	0·150					
3			1·50	7·69	0·160	1·23	0·0208			
1	24 lt	no plastic	1·26	6·46	0·122		0·0189			
2			1·38	7·08	0·132					
3			1·44	7·48	0·168					
4			1·46	7·49	0·286	2·14	0·03821			
1	24 lt	n.p. inverted	1·250	6·41	0·134		0·0209			
2			1·410		0·166					
3			1·480		0·354					
4			1·540	7·90	0·388					
5			1·620	8·31	0·428					
6			1·70	8·72	– ?	3·75	0·0491			
1	24 lt	n.p.	1·180	6·05	0·106		0·0175			
2			1·320		0·128					
3			1·520	7·79	0·286					
4			1·620	8·31	0·390					
5			1·620	8·31	0·470	3·90	0·0566			
1	24 lt	n.p.	1·150	5·90	0·106		0·0180			
2			1·380		0·148					
3			1·420	7·28	0·164					
4			1·50	7·69	0·294	2·26	0·03821			
1	24 lt	n.p.	1·19	6·10	0·110		0·0180			
2			1·30		0·130					
3			1·44		0·164					
4			1·46		0·282					
5			1·52		0·334					
6			1·62		0·384					
7			1·66		0·408					
8			1·74	8·92	0·446					
9			1·78	9·13	0·474					
10			1·80	9·23	0·544	5·02	0·0589			
1	24 lt	n.p.	1·16	5·95	Kept on for half an hour.	0·6	plug fused at	some time	in that period	
1	24 lt	plastered	1·08	5·54	0·098		0·0177			
2			1·48		0·170					
3			1·80		0·486					
4			2·00	10·26	0·598					
5			1·94	9·95	0·960	9·6	0·07960			
1	24 lt	plastered	1·16	5·95	0·148		0·025			
2			1·44		0·430					
3			1·72	8·82	0·580					
4			1·80	9·23	0·720	6·7	0·0780			
1	24 lt	plastered	1·22	6·26	0·104		0·0167			
2			1·52	7·79	0·166					
3			1·74	8·92	0·412	3·7	0·04621			
1	18 lt	no plastic	0·55	2·82	0·074		0·02621			
2			0·63		0·088					
3			0·68		0·10					
4			0·75		0·114					
5			0·82		0·134					
6			0·85		0·142					
7			0·90		0·158					
8			0·95		0·180					
9			0·98		0·366					
10			1·03	5·28	0·396					
11			1·12	5·74	0·434					
12			1·15	5·90	0·580	3·4	0·0983			

Number of fuse	Condition	Obach	Amperes	P.D. Volts	Energy in fuse	Res. of fuse	Ratio of Res.	Drop of wire
18	no plaster	0·91	4·67	0·196		0·0420		
		1·00	5·13	0·201	1·03	0·0392		
18	no plaster cap inverted	0·89	4·57	0·1146		0·0319		
		1·0	5·13	0·176				
		1·08	5·54	0·320	1·77	0·0579		
18	no plaster cap not inverted	0·90	4·62	0·190		0·0411		
		1·01	5·18	0·408				
		1·05	5·39	0·500				
		1·10	5·64	0·550	3·1	0·0975		
18	no plaster	0·89	4·57	0·1821		0·0398		
		1·0	5·13	0·426				
		1·05	5·39	0·480				
		1·15	5·90	0·546				
		1·20	6·15	0·602				
		1·31	6·72	0·970	6·5	0·1446		
18	plastered	0·93	4·77	0·170		0·0356		
		1·08	5·54	0·230	1·27	0·0415		
18	plastered	0·91	4·67	0·180		0·0386		
		1·06	5·44	0·486				
		1·14	5·85	0·558				
		1·22	6·26	0·730	4·57	0·117		

Resumé of Results.

Fuse	Res. at normal temp.	Res. at fusing temp.	Mean current fusing (Current wiring 37°) no plaster	Mean energy fusing no plaster	Mean current fusing no plaster	Mean current fusing no plaster	Mean current fusing plaster	Mean current fusing plaster	Mean current fusing plaster	Drop at fusing energy no plaster
37	0·0080	0·0160	12·8 ± 0·1	2·62 watts	–	–	22·8	–	–	0·204 volt
30	0·009	0·018	11·5	2·38 "	11·9	12·9	13·6	–	–	0·207 "
24	0·016	0·035	7·6 ± 0·05	2·20 "	8·5	9·2	10·0	9·2	8·9	0·290 "
18	0·025	0·065	5·5 ± 0·15	1·93 "	5·6	6·7	–	–	5·9	0·350 "

The effect of adding plaster of paris is to retard the fusing and for currents delivered within three minutes to increase the fusing current from 10% for the smallest to 80% for the largest fuse tested.

Removing the cover of a fuse has little effect upon its fusing point.

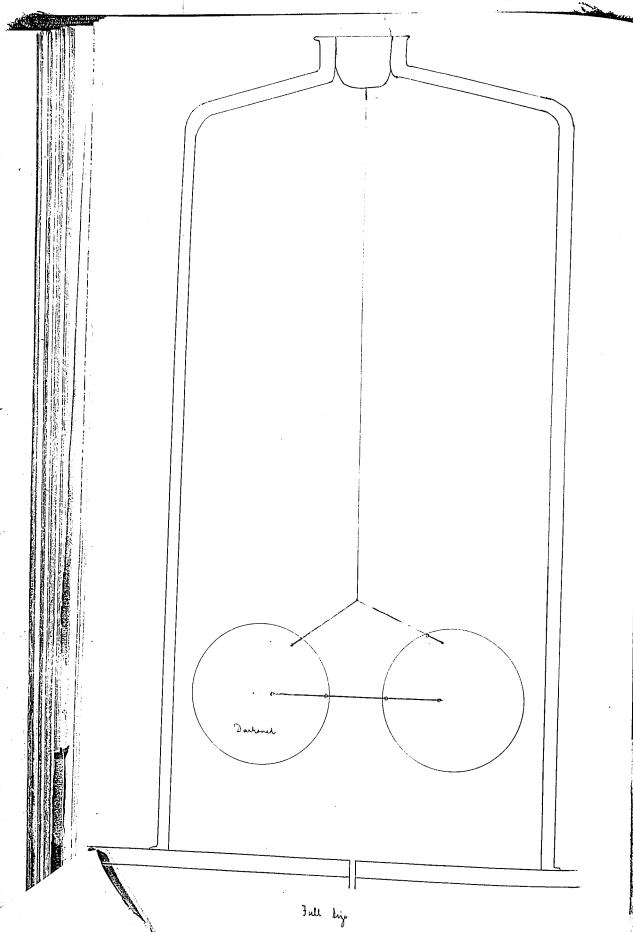
Adding water to a fuse round the wire does not produce a very great effect on the fusing current. In one case had the latter increased 10%.

Inverting a fuse, and particularly setting on its edge increases the fusing current for fuses without plaster. It has little effect on plastered fuses.

The fusing current ~~nearly~~ causes the res. of the fuse to increase between 2 and 3 times.

The drop on a fuse at fusing point is from 0·35 volt for the 18 size to 0·20 volt for the 37 size.

A current long continued will melt a fuse about 20% below the value here given



On the angle of Deflection obtainable from a Disk suspension in vacuo according to Clerk Maxwell's electromagnetic theory of light

Let l be the length of the supporting fibre of single silk.
" r " " mean effective radius of luminous action.
" a " " area on which that force is concentrated.
" θ " " angle of deflection produced in abs. measure
" m " " moment of torsional rigidity of the fibre referred to unit rod.
" f " " pressure due to luminous action in abs. measure.

Then equating moments round the fibre we

$$f a r \cos\theta = \theta m$$

If we keep the limits of deflection small $\cos\theta$ will not differ greatly from 1, and $\theta = \frac{far\,l}{m}$

Assume the following values.

f for sunlight see page 59 Record Book II = ~~70 microdynes~~ page by Maxwell's theory or 3.5×10^{-5} dynes per sq. cm. for powerful sunlight. take $f = 1 \times 10^{-5}$ dynes

$a = 10$ sq. cms.

$r = 10$ cms.

$l = 100$ cms.

$m = 2.5 \times 10^{-3}$ see Phil Mag. Jan. 87 T. Gray.

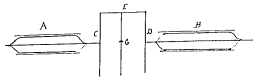
Then $\theta = \frac{10^{-5} \times 10^{4}}{2.5 \times 10^{-3}} = \frac{10^{2}}{2.5} = 40$

or the power exerted by sunlight even 1/10 full intensity should drive the disk with an energy capable of introducing 40 radians or 7 complete turns in the fibre. It is very evident therefore that a disk so suspended should completely test the accuracy of Maxwell's theory.

Required, a mica disk 3.57 cms diam or an arm 10 ~ 1.70 = 8.22 cms long.

The opposite diagram represent the actual arrangement Diameter of vanes 5.1 area 20.42 sq. cms. Radius 3.5 cms effective The fibre is of single silk from the cocoon carefully washed in hot water. Its length is about 18 cms. The suspension is of fine glass rod drawn out in a flame, and secured to the mica vanes with shellac. The left hand vane shewn was darkened by coating with a film of collodion containing lampblack dissolved in ~~methyl~~ ether acetate. The other vane was left uncoated except near the horizontal tie end. The weight of the whole suspension was 0.320 gms. It was secured to the ground glass stopper of a receiver for the air pump.

With air in the receiver, which is secured supported on a pier there seems to be no repose for the suspension which keeps moving slowly in a most erratic manner apparently owing to convection draughts within caused by slight inequalities of temperature.



The two motors will thus be in unstable condition of speed. Whatever changes be made in the strength of their fields will produce no movement of the car and no change in relative velocity if the motors be frictionless, and the only changes possible in their relative velocities will be changes due to friction in the motors.

Let n_1 be the revs. per sec.

Then $n_1 \varphi_1 w + n_2 \varphi_2 w$ + full f emf in armature = E

$n_2 \varphi_2 w + n_1 \varphi_1 w = \frac{E_1}{\rho_a}$ where E_1 = available emf

if $x = 1$ $\quad n_2 = \frac{E_1}{\varphi_2 w(y+1)}$

Whatever value y may have there is some value of x common to both motors at which they will do least work.

Problem. Required the Equation of motion and complete solution of the following case:—

Two similar motors have their armatures A and B in line, and geared together by mitre gearing C D and E. The differential wheel E is fed to revolve on its axis but the axis is on an arm revolving on another G in line with the armature axes. G communicates directly with the car wheel or is itself the car wheel shaft. When A and B are running in opposite directions at the same speed, F spins on its axis with the linear velocity at the pitch line of each but the arm FG is at rest. As now the speed of one motor is increased, that wheel exceeds in velocity and OF revolves thus driving the car. If the armatures are in series, but the fields are separately excited, find the condition of traction.

Let w be the number of wires counted round each armature.

" n_1 n_2 " " revs. of A & B respectively per sec.

" φ_1, φ_2 " " total flux $\times 10^{-8}$ (passing) thro' A & B respectively in C.G.S.V.

" ρ " " resistance of each armature in ohm

" E " " constant E.M.F. maintained on supply.

" m " " moment of inactive effort of the car on FG referred to mitre radius

" μ " " " total friction in each armature shaft assumed uniform

" $n_1 = x\, n_2$

" $\varphi_2 = y\, \varphi_1$

Then " η_1, η_2 be the internal e.m.fs generated by the armatures

$$\eta_1 = \varphi_1 n_1 w \qquad \eta_2 = \varphi_2 n_2 w$$

$$\text{current } c = \frac{E - w(\varphi_1 n_1 + \varphi_2 n_2)}{2\rho} = \frac{E - w\varphi_1 n_2 (x+y)}{2\rho}$$

$$\text{Energy absorbed} = c(\eta_1 + \eta_2) = \frac{w\varphi_1 n_2 (x+y)\{E - w\varphi_1 n_2 (x+y)\}}{2\rho}$$

" counted $= 2\pi\mu n_2 (x+1) + m\pi n_2 (x-1)$

$$= \pi n_2 \{2\pi\mu (x+1) + m(x-1)\}$$

$$\therefore\ w\varphi_1 n_2 (x+y)\{E - w\varphi_1 n_2 (x+y)\} = 2\pi\rho n_2 \{2\mu(x+1) + mx - 1\}$$

This expresses the relation of x to y when the other values are forthcoming.

Let $w\varphi_1 n_2 = J$ $\quad$ To find x

$$J(x+y)\{E - J(x+y)\} = 2\pi\rho n_2 \{2\mu(x+1) + mx - 1\}$$

$$EJ(x+y) - J^2(x+y)^2 =$$

$$x^2 J^2 + x(EJ - 2J^2 y - 4\pi\rho\mu n_2 - 2\pi\rho n_2 m) = -EJy + J^2 y^2 + 2\pi\rho n_2 (2\mu - 1)$$

In this equation first neglect the frictional terms μ for a simpler approximation. Then

$$J^2 x^2 + x(2J^2 y - EJ + 2\pi\rho n_2 m) = EJy - J^2 y^2 + 2\pi\rho n_2$$

Whence $x = \dfrac{EJ - 2J^2 y - 2\pi\rho n_2 m}{2J^2}$

$$\pm \frac{\sqrt{(2J^2 y - EJ + 2\pi\rho n_2 m)^2 + 4J^2(EJy - J^2 y^2 + 2\pi\rho n_2)}}{2J^2}$$

when $m = 0$ $\quad x = \dfrac{EJ - 2J^2 y \pm J\sqrt{E^2 + 8\pi\rho n_2}}{2J^2} = \dfrac{E - 2Jy \pm \sqrt{E^2 + 8\pi\rho n_2}}{2J}$

$= -y$ approximately.

when m becomes large $x = 1 - y$ " approximately

Problem.

A pulley 18" in diam. travels at a peripheral speed of 4000 feet per minute. It transmits at that speed a maximum activity of 12 horse-power. The belt encircles half its circumference. Find the least tension on the belt consistent with no slip at that delivery.

The pull on the belt, (difference of tension), will be

$$\frac{33,000 \times 12}{4000} = 99 \text{ lbs weight.}$$

The pull on the driving side will be $1.875 \times$ pull on following side.

$$99 + x = 1.875\,x$$

$$0.875\,x = 99$$

$$x = 113 \text{ lbs.}$$

For $\mu = 0.2$ The tension must be 212 lbs. on the driving side
113 " " " following side
and the mean tension at rest 163 lbs. weight.

Electrical Radiance experiments.

The receiver shown in diagramatic section facing p. 64 was exhausted by the Edelmann air-pump. In doing so the first time, an accident occurred which broke the top glass rod of the suspension. This was replaced with another very similar one, the constants of the apparatus therefore not altering greatly. The receiver was then exhausted till the pumpgauge showed no difference of level, probably representing about 0.4 mm of pressure. Inside the receiver, a similar gauge was placed to mark the maintenance of vacuum. The apparatus was then placed on one of the brick piers, and a beam from an arc light some 4 metres distant focussed upon it by a spherical mirror some 2 metres beyond. The heat of this beam was found to melt the shellac on the vanes and a screen had to be interposed, in the form of a water cell between glass sides. When the beam was thrown on the darkened vanes, the latter moved slowly towards the beam. Owing to the refraction of light passing through the wall of the glass receiver it was not possible to keep the plain vane in shadow. Finally with the beam directly on both vanes or in the centre between them the suspension slowly set parallel with the beam.

A weaker beam from a second more distant mirror was now thrown at right angles upon the apparatus, the first beam being suppressed. In about 20 minutes, the suspension was found to have turned to 45° or midway between the two directions.

The second beam was now suppressed and the original beam restored. In thirty minutes the suspension retreated 25° or so and was within some 20° of parallelism to the original beam.

It seems therefore that the suspension has a tendency to set itself along the beam, but whether from a true radiant pressure or from a convection effect in the rarefied air is not yet known. The plain mica seems to be most rapid. The deflections were slow but definite, and there was no wandering action.

Problem. A Crookes radiometer has an estimated mass of 0·5 grammes, and an estimated radius of gyration of 1 cm. A certain intensity of light produces in it a velocity of 70 revolutions per minute or an angular velocity $\frac{d\theta}{dt}$ of $2{\cdot}333\,\pi$. On intercepting the light the flywheel comes to rest in 15 seconds. Find the moment assumed uniform of friction round the axis.

The moment of inertia $= 0{\cdot}5 \times 1 \times 1 = 0{\cdot}5$ cm²gm.

" angular acceleration $\frac{d^2\theta}{dt^2} = \frac{2{\cdot}333\pi}{15} = 0{\cdot}4889$

" moment of friction $= 0{\cdot}244445$

The energy possessed by the flywheel at full speed $\frac{I}{2}\left(\frac{d\theta}{dt}\right)^2 = 13{\cdot}75$ ergs.

Standard Daniell cell for Bergmann & Co.

A c.p. zinc cylinder electroplated with zinc was opposed to a cp copper cylinder electroplated with copper. These were respectively immersed in a solution of $ZnSO_4$ 1·400 and $CuSO_4$ 1·100 @ 15°C respectively, these solutions being prepared with great care.

On first connecting up the cell a distinct e.m.f amounting to 0·86 volt was found in the reverse direction to that of the Daniell element. On examination this error was traced to the presence of an air bubble at the end of the capillary tube dipping in the $CuSO_4$. On expelling this bubble the E.M.F. immediately changed again to 1·090 volts. On closing the cells circuit through 1000 ω the p.d. fell to 0·01 volt showing the int. res. to be 12,000 ω. After cleaning the zinc plate with fresh glass-paper and replating the copper plate, the EMF returned to 1·078 volts.

Cautery Battery Test for The Edison Manufacturing Co. N. Y.

Eight elements of the double plate (3 zincs - 2 CuO frames) 300 amp. hr. type but in black g.p. cells of rectangular form, were enclosed in one box in two rows of four. The cells when charged held 1500 c.c. of solution sp.g. 1·26. A strip of german silver wound on a reel is included in the circuit.

The e.m.f. of the cells first made up was 7·3 volts = 0·91 p.c. The current started at 8·50 28th May. Two black ring, heavy leads, g.s. strip and knife cautery. The current was 18·8 amperes, the p.d. on the knife 0·667 volt (0·0355 ω)

The current was maintained until 15.50 making a total of 7.¾ hours or 131 ampere hours. The strength of the cells was at first a little in excess, but finally was just enough in ten or fifteen minutes after closing the circuit.

Continuation of Experiments on Telephone Battery (Edison-Lalande) from page 53.

The zinc in the cells were found to have lost so much since their last weighing, that some of them were replaced. They were then all arranged in numbers stamped upon them. It is supposed that the short circuiting which takes place in the cell is due to the bridging at the surface of the solution by a large number of small floating particles of metal. To prevent this from happening the plates are being now coated at the top with a varnish of gutta percha in $CHCl_3$ followed by a varnish of gum lolate in CS_2. This coat is carried down beneath the surface of the liquid. There are no couplings, the plates being separated by spreading them apart. New filtered solution was added to each cell.

No. of Cells	Weight of zinc gone 28.7.95									
1	30·305									
2	29·120									
3	33·945									
4	34·760									
5	32·000									
6	33·135									
7	41·600									
8	35·140									
9	31·290									
10	32·340									
11	33·965									
12	34·130									
13	33·458									

Alternating P.D.s for supplying lamps.

Mr R. Lozier found that at Station = Island the lamp circuit that had to be supplied gave 35°·30′ deflection on our Gardew Voltmeter. This was represented by 53 volts of continuous-current pressure here. The lamps should therefore be 53-volt lamps, and the mean alternating p.d. was 47·7 volts. If e be the instantaneous emf expressed by the relation

$$e = E \sin pt \qquad \text{where } n = \frac{2\pi}{p}$$

Then the energy delivered in one period thro a lamp of resistance r is

$$\frac{E^2}{r}\int_0^T \sin^2 pt\, dt. = \frac{E^2 T}{r\, 2}$$

so that a continuous current of $\frac{E}{\sqrt{2}}$ would produce the same heat

but $E = \frac{\pi}{2}\eta$ if η is the mean alternating emf.

$\therefore$ a continuous current of $\frac{\pi\eta}{2\sqrt{2}}$ or $1{\cdot}1\eta$ would produce the same effect

or $E = \frac{\pi\eta}{2\sqrt{2}}$

$\eta = 0{\cdot}9\,E$.

On the energy of luminiferous Ether.

Let the energy imparted to the surrounding ether by a ~~known~~ radiating point in space be η ergs per second, uniformly. Then in time t the energy delivered will be

$$E = \eta t$$

and the distance to which the disturbance will have travelled in every direction, is $r = vt$ where $v = 3 \times 10^{10}$ cms.

The volume V occupied by disturbance will be a sphere of

$$V = \frac{4\pi r^3}{3} = \frac{4\pi v^3 t^3}{3}$$

and the volume occupied per sec: or rate of expansion

$$\frac{dV}{dt} = 4\pi v^3 t^2$$

or $$dV = 4\pi v^3 t^2 dt$$

but this volume is filled by a quantity of energy delivered in time dt or $= \eta\, dt$

so that the energy per unit volume $\frac{dE}{dV}$ occupying this space

is $$\frac{dE}{dV} = \frac{\eta}{v} \times \frac{1}{4\pi r^2}$$

$$= \frac{\eta}{v} \times \frac{1}{S}$$

where S is the spherical surface considered.

The apparatus employed in the experiment on Electrical Radiation recorded in Book II p. 140 was again utilised. The lamp tube was sealed by seal into the main tube of the swinging vane, so that the latter should be directly under the influence of the rays of the 50 c.p. lamp. To ascertain the moment of torsion of the arrangement, a tin sphere 2·54 cms. in diam and weighing 62·23 gms was suspended by 1y. cms. of the same kind of platinum wire used in the suspension. The moment of inertia of the sphere would be

$$62 \cdot 23 \times 0 \cdot 4 \times 1 \cdot 613 = 40 \cdot 15 \text{ cm}^2\text{gms.}$$

This sphere executed 16 complete vibrations in 9 minute 0 sec. or find a period of approximately 33·75 secs.

The torsional rigidity of the wire is expressed by the equation

$$\tau = I\left(\frac{4\pi^2}{t^2}\right)$$

$$= \frac{40 \cdot 2 \times 19 \times 40}{33 \cdot 75^2 \times 33 \cdot 75} = \frac{40 \cdot 2 \times 760}{1139} = 26 \cdot 8 \text{ dyne cms.}$$

The length of the suspending wire in the radiance tube is about 10 cm so that the moment necessary to produce 1 deflection is 2·7 dyne cms

If the lamp absorb 150 Watts, 8% of that energy will be radiated as light. but $\frac{1 \cdot 5 \times 10^7}{3 \cdot 0 \times 10^{10}} \times \frac{1}{1200} = \frac{1}{20} \times \frac{1}{1200} = \frac{1}{24000} = \frac{1}{2 \cdot 4 \times 10^4} = 4 \times 10^{-5}$ erg

will be the energy at the disk per sec. But of this energy half should be numerically equal to the pressure say 20 microdynes. Now suppose that only 10% of all the energy in the carbon spiral due to the tube really enters it. Then the pressure will be 2 microdynes at a radius of 6 = 12 microdyne cms and the angle should be therefore

$$\frac{2 \cdot 9}{20 \times 10^6} = 10^{-5} = \frac{5 \cdot 7}{10^5} = 0 \cdot 00 \frac{3442}{10^5} = \frac{2011}{100} = 2'' \text{ of arc.}$$

On the Power required to operate a small Illuminating Plant for the Rick Telescope.

Six lamps of four candle power each are required three hours daily. A sample 16 c.p. lamp here takes 1.25 ampères at 9 volts p.d. Six of these = 7.5 ampères so that a battery of the double-plate Edison=Lalande type would easily operate it.

$$0.7x - 7.5 \times 0.03x = 9$$
$$0.475x = 9$$
$$x = 19$$

These would last certainly 250 amp: hr. = 33 hours.
= 11 days.

The energy absorbed would be $9 \times 7.5 = 67.5$ Watts $= \frac{1}{10}$ HP. say 10 cents per hour. or 30 cents daily. \$120 per annum.

Constants of the Smaller Cathetometer.

The screw has forty threads to the cm. Each revolution is divided into 100 parts and each hundredth can be read to 5 lb and estimated to 20 lb that is the instrument measures the $1/200000$ lb part and estimates the $\frac{1}{80,000}$ lb part of a cm. i.e. measures 5×10^{-5} and estimates 1.125×10^{-5}. One division of the vernier produces a motion movement of the optic axis (not exceeding) the wave length of sodium light. D. The instrument is in focus when the object is 6.0 cms from the object glass and the back lash is about 5 divs on the hand $\frac{1}{20}$ lb no or $\frac{5}{200}$ lb cm $= 1.125 \times 10^{-5}$

Constants of the Spherometer

The screw has forty threads to the cm, and its zero for a plane surface is 5.332. It measures the $\frac{1}{40000}$ lb of a cm. having 100 divs round the circle. $= 2.5 \times 10^{-6}$ cm.

By cathetometer the radius was too great to measure but by scale the distances

AB	5.64	OA	3.23	Mean 3.22 cm
BC	5.56	OB	3.205	
AC	5.62	OC	3.22.	

If x is the distance measured off in cms.

Rad: of curvature $R = \frac{5.184}{x} + \frac{x}{2}$

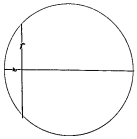
Curvature $\frac{1}{R} = \frac{2x}{5.184}$ or $0.192g\,x$ approximately.

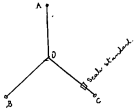
with the graduation of the instrument

$$R = \frac{207.36}{y} + 20y$$

$$\frac{1}{R} = \frac{y}{207.36} \text{ or } 0.00482 2y \text{ approximately. (c.o.s.)}$$

$0.4822\,y$ in dioptries (metre)





$x : r :: r + 2R - x :$

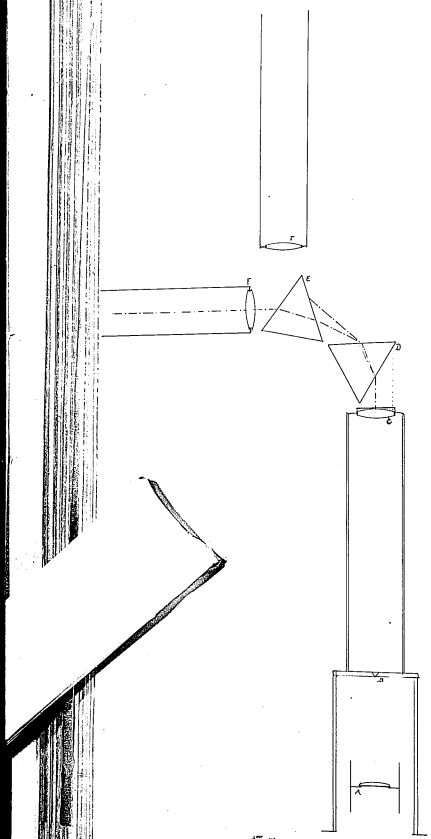
$2Rx = x^2 + r^2$

$R = \frac{x^2 + r^2}{2x} = \frac{r^2}{2x} + \frac{x}{2}$

$r^2 = (3.22)^2 = 10.368$

$\frac{r^2}{2} = 5.184$

$R = \frac{5.184}{x} + \frac{x}{2}$



Optical Measurements.

Glass lens No 1 Diam. 12·6 Plano convex $R = 42.5$ $C = 0.2615$
Large spherical Mirror no 1. $R = \cancel{\ldots}$ $C = 0.5885$ $F = \cancel{\ldots}$ cm
165·6 157·5

The radius of curvature of the glass by spherometer is 165·6
- " " " " " mercury - optical method - 157·5
- mean focal distance length 315.
- diameter of the aperture 33
- semi vertical angle taking $r = 160$ 5°55′
- solid angle subtended $\left(\frac{\text{area}}{r^2}\right)$ 0·03355
- area of reflecting surface 857. sq cm
- curvature 0·61 dioptrie or in C. G. S. U. 0·0061

Large spherical mirror no. 2

The radius of curvature of the glass by spherometer 161
- " " " " " mercury - optical method 150
- mean focal length 300
- diameter of the aperture 33
- semi vertical angle taking $r = 150$ 6°19′
- solid angle subtended 0·038815
- area of reflecting surface 858
- curvature 0·667 dioptrie or in C. G. S. U. 0·00667

On the Machines Required for the Lick Observatory Lights.

Contd from p. 70.

If the lamps are operated by a storage plant, then for 9 volts five would be required, and for a duplicate set 10. The capacity would be 22·5 amp hrs per diem say 25 with loss = 200 amp. hrs. for 8 days.

To charge these daily would be to supply 22·5 ampere for one hour.

The diagram on the opposite page represents the essential part of the stillson spectroscope in principal section ½ size. A is a cylindrical lens with plane face downwards and of 7 cm. focus. At or near its focus is the slit B, which is also in the principal focus of the ~~plano~~ convex lens (19 cm) C. D and E are equilateral prisms. F is a similar ~~plano~~ convex lens of 19 cm P.F. and the image it forms is examined by double eyepiece positive at the end of the drawtube.

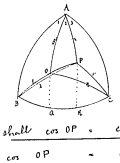
By spherometer the inner surface of the object glass in the Edison equatorial is plane, the reading of the outer surface being 3·39 thousd = $\frac{3.39}{240}$ cms, so that the radi of curvature is $\frac{5.1816}{3.39} \times 240 = 61.18$ cms, and the curvature $\frac{1}{R} = 0.01635$ c.g.s. or 1·6350 dioptrie.

By trial, the focal distance is about 163·5 cms.

Aperture 10·5 cms diam. (4·1/2″).

On another occasion an arc light distant 300 cms from the object glass was focussed 172 cms on the other side.

Proof of a continually recurring theorem in spherical trigonometry.



If ABC be a quadrantal spherical triangle formed by three equal rectangular coordinates, and OP be any arc, also if the direction angles are as shewn then.

shall $\cos OP = \cos l \cos\lambda + \cos m \cos\mu + \cos n \cos\nu$.

For $\cos OP = \cos m \cos\mu + \sin m \sin\mu \cos A_2$

$$\cos A_2 = \cos\left[\frac{\pi}{2} - (A_1 + A_3)\right]$$

$$= \cos\frac{\pi}{2}\cos(A_1 + A_3) + \sin\frac{\pi}{2}\sin(A_1 + A_3)$$

$$= \sin A_1 \cos A_3 + \cos A_1 \sin A_3$$

$$= \cos(A_1 + A_3)\cos A_3 + \cos A_1 \cos(A_1 + A_3)$$

$$= \frac{\cos n}{\sin m}\,\frac{\cos\nu}{\sin\mu} + \frac{\cos l}{\sin m}\,\frac{\cos\lambda}{\sin\mu}$$

$$\therefore \cos OP = \cos l \cos\lambda + \cos m \cos\mu + \cos n \cos\nu.$$

q.e.d.

On the Mean Amplitude of Sound Vibrations in air as deduced from the energy of vibration per unit volume.

(72)

Let the excursion of an air molecule from its position of rest at any moment, under vibration be x

- the period of vibration - T
- " frequency - - - $\nu = \frac{1}{T}$
- " amplitude - - - a having a maximum A
- " energy - the molecule be - e - - - E
- " mass - - - - m
- " n. of molecules per unit vol - n
- " mass of all the molecules - - - $M = mn$

Then we have if time be reckoned from the instant of excursion

$$x = A \sin\left(\frac{2\pi t}{T}\right)$$

$$\therefore \dot{x} = \frac{2\pi}{T} A \cos\left(\frac{2\pi t}{T}\right)$$

$$\therefore e = \frac{mn}{2}\frac{4\pi^2}{T^2}A^2 \cos^2\left(\frac{2\pi t}{T}\right)$$

$$\therefore e_{mean} = \frac{2\pi^2 mnA^2}{T^3}\int_0^T \cos^2\left(\frac{2\pi t}{T}\right)dt$$

$$= \frac{2\pi^2 mnA^2}{T^3}\left[\frac{2\pi t}{2T} + \frac{\sin\frac{4\pi t}{T}}{4}\right]_0^T$$

$$= \frac{2\pi^2 mnA^2}{T^2}(\pi)$$

$$= \frac{2\pi^3 mnA^2}{T^2}$$

$$\therefore A^2 = \frac{eT^3}{2\pi^3 mn}$$

$$A = \frac{\sqrt{e}}{\sqrt{(2T^3\pi^3 mn)}}$$

$$= \frac{\sqrt{e}}{\sqrt{2T^3\pi^3 M}}$$

For dry air at 0°C and pressure of 1 megadyne per sq cm,

$$M = 1.28 \times 10^{-3}$$

For the note do $\nu = 256 \times 10^2$ $\quad T^3 = 1.678 \times 10^7$

$\pi^3 = 3.14 \times 10^1$

denominator $= \sqrt{(1.28 \times 1.678 \times 3.14 \times 10^5)}$

$= \sqrt{6.7444 \times 10^5}$

$= \sqrt{67.444 \times 10^4} = 821$

$A = 0.00122\sqrt{e}$

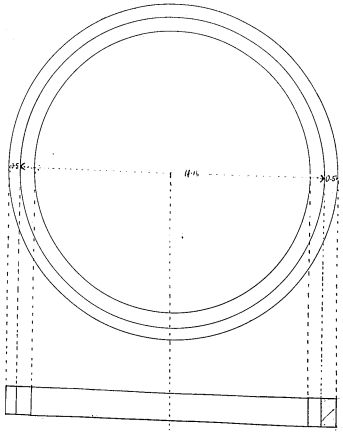
The maximum amplitude is therefore about one thousandth of the mean energy per c.c. stated in ergs.

Also $c = \dfrac{e - \varphi n w 10^{-8}}{r}$

$$= \frac{e}{r} - \frac{\varphi n w 10^{-8}}{r}\left(\frac{e}{\varphi n w 10^{-8}} - \frac{2\pi r M}{\varphi^2 n^2 w^2 10^{-16}}\right)$$

$$= \frac{2\pi M}{\varphi n w 10^{-8}}$$

Consequently. If the moment is constant the current will be constant at all speed.



Conditions for a motor to act as a Meter.

A motor whose field is supposed to be maintained uniform, drives under a varying e.m.f. e. find the conditions that the speed shall be proportional to e. (ills)

Let φ be the uniform flux c.G.S. U.

n - - no. of revs. per sec.

w - - - wires all round the armature.

γ - - counter e.m.f. (volts)

r - - - res: of the armature (ohms)

c - - current strength (amperes)

μ - - moment due to magnetic resistance

m - - - - - mechanical friction

ν - - - - - vane movement.

Then $e = c\mathcal{R} + \varphi n w \times 10^{8}$ equation of e.m.f.

$ec = c^2 r + 2\pi n(\mu + m + \nu)$ energy

From these c can be eliminated, and n expressed in terms of the remaining quantities.

$$e^2 - e\gamma = c^2 + \gamma^2 - 2e\gamma + 2\pi r n(\mu + m + \nu)$$

$$\therefore\ n = \frac{e\gamma - \gamma^2}{2\pi r(\mu + m + \nu)} = \frac{\varphi n w 10^{-8}(e - \varphi n w 10^{-8})}{2\pi r(\mu + m + \nu)}$$

$$2\pi r(\mu + m + \nu) = e\varphi w n^{-1} - \varphi^2 n^2 w^2 10^{-16}$$

$$n = \frac{-2\pi r(\mu + m + \nu) + e\varphi w 10^{8}}{\varphi^2 w^2 10^{16}}$$

$$= \alpha e + \beta$$

$$\frac{dn}{de} = a$$

The variations in speed will therefore be proportional to the variations of emf provided that the moments of friction and work at the axle are all independent of the speed, or that their sum is independent.

It is required to construct a motor which shall operate on 0.5 volt and make 500 revs. per min: on that amount. It must be as light as possible.

Suppose the int: diam: of the gramme ring to be 4.5 = 11.16 cms, and that the ring is of ~~triangular~~ section and 0.5 sq. cm.

If φ be 17000 $\varphi = 8{,}500$

for $n = \dfrac{500}{60} = 8.33$

$$0.5 = 8.5 \times 10^{3} \times w \times 8.33 \times 10^{-8}$$

$$\therefore\ w = \frac{0.5 \times 10^{5}}{70.81}$$

$$= 706$$

This is the number of wires which would drive 500 revs. per min when 0.5 volt is generated

It is desirable to have the starting moment as great as possible. Calling R the ext. radius this moment $\mathfrak{M}$ is

$$\mathfrak{M} = \frac{cw\varphi}{\pi R}$$

c being in abs measure
φ - - - -

The breadth of the armature being (on min) b and the depth a

- diameter - wire. (copper) - d
- thickness - insulation - t
- diameter covered - D
- number of layers - l

Then approximately

$$w = \frac{2\pi(R - \tfrac{1}{2}b)}{D} \times l$$

$$c = \frac{e}{\frac{2w(2a+2b)\rho}{\pi d^2}} = \frac{e\pi d^2}{2\rho w(a+b)}$$

$$w\varphi = \frac{e\pi d^2\varphi}{2\rho(a+b)}$$

and

$$\frac{w\varphi}{\pi R} = \frac{ed^2\varphi}{2R\rho(a+b)}$$

(all in abs. measure)

Consequently to a first approximation the starting moment with a given e.m.f. e is proportional to the square of the diameter of the wire, and inversely to the radius.

With 700 wires in two layers, there will be 350 on the first layer. The diam is 11·16 cm so that the allowance being made for insulation sections 360 wire must fit in 34 cm. = 0.0134 = 0.037". Allowing 0.005" for silk leaves 0.032" = #21 B.W.G.

The length of one turn will be $2(0.2 + 0.1) + 8 \times 0.03 = 1.5$". 700 turns = 1050" = 90 feet nearly. and the res: will be $\frac{90 \times 0.01}{4}$ = 0.225.

Supposing now that the full load is represented by 0·5 volt with 25 lamps, 1 lamp will give 0.02 volts. The current generated by this will be $\frac{0.02}{0.225}$ = 0.089 amperes. The starting moment will be

$$\frac{0.89 \times 10^{-1} \times 7.0 \times 10^2 \times 5.5 \times 10^3}{3.14 \times 5.5} = \frac{53.0 \times 10^4}{17.27} = 30{,}670$$

$$\frac{0.0220 \times 10^6 \times 0.81 \times 0.81 \times 8.5 \times 10^3}{2 \times 5.5 \times 1.7 \times 10^3 \times 1.5} = \frac{11.15 \times 10^7}{129.9 \times 10^3} = 3.73 \times 10^4$$

This moment of 30,670 dyne cms is equivalent to a couple of $\frac{30{,}670 \times 5.5}{981}$ at the circud. = 168 grammes = $\frac{1}{5}$ lb oz.

Solution for a speed of 150 revs per min and 1·0 volt at full load.

$$w = \frac{1.0 \times 10^8}{8.5 \times 10^3 \times 2.5} = \frac{100 \times 10^6}{21.25 \times 10^3} = 4.70 \times 10^3 = 4{,}700.$$

Since however there will be considerable fall of potential in an armature with so many turns, there will be a lower e.m.f generated, and we need only have 4,000 wire say.

These can be arranged in five layers of 800 or 4 of 1000.

in the first case, the diam will be $\frac{34}{800} = \frac{0.34}{8} = 0.043$ cm = 0.017" = 0.013"

- - second - - - - - $\frac{34}{1000} = 0.034$ cm = 0.0136 = 0.0096"

Assuming the first case 5 layers of 800 #29 B.W.G. 0.013"
The length of each turn will be 1.5" and 4000 turns = 6000"
= 500 feet ≈ 0.061 : 30.5 cm ÷ 1.4 = 7.6 cm and
The current that will at 100 volts through this will be for 25 amp
(full load) $\frac{1}{7.6}$ ampere, and for 1 amp $\frac{1}{7.6 \times 25} = \frac{1}{190} = 0.0053$ ampere.
The starting moment will be $\frac{1}{2} \times \frac{c u \omega}{\pi R} = \frac{1}{2} \frac{5.3 \times 10^{-1} \times 4.0 \times 10^{3} \times 8.5 \times 10^{3}}{3.142 \times 5.5}$

$$= \frac{1}{2} \frac{21.2 \times 10^{-1} \times 8.5 \times 10^{3}}{17.28} = \frac{1043}{2} \text{ dynes cm.}$$

$$= \frac{189.6}{2} \text{ dynes acting at inner periphery.}$$

$$= 0.193 \text{ grammes.}$$

$$= 0.097 \text{ "}$$

In as much as there will only be 1 sq. cm. of iron section through the armature (0.5 on each semi circumference), it will be unnecessary to have the iron in the core more than 5 sq. cm. for wrought iron or 10 sq. cm. for cast iron.

Allowing a clearance of 0.1 the maximum entrefer will be 0.4
The surface over which the flux enters is

$$3.14 \times 12.5 = 39.27 - 7.3 = \frac{32}{2} = 16 \text{ cms} \times 1 = 16 \text{ sq. cm}$$

The magnetic resistance is thus $0.4 \div 16 = 0.05$ units.
and the m.m.f. ~~exciting~~ power necessary for 17,000 lines is

$$17000 \times 0.05 = 850 \qquad \therefore 1.257\, AT = 850$$

$$\text{or amp} = 676$$

Suppose the magnets to be 6 cms long, and 4 cm in diam. The radiating surface will be 25 sq. cms. on each = 50 sq. cms. in all. Then allowing 20 sq. cms. per watt we have 2.5 Watts absorbed in the magnets. At 100 volts this will mean a current of $\frac{2.5}{110} = \frac{2.5}{1100} = 23$ milliamperes. The resistance of the magnets will therefore be $\frac{110}{23} = 0.023$ or $\frac{1}{\rho} = 47.80$ or = 24.00 in cal.

The diam. of the core will be 2.52 cm, the external diameter for trial 5 cm, and the length 6 cm. Then the coiling space = $6 \times 0.7854\,(25 - 6.35) = 87.9$ c.c.
and with silk covered wire $d = 0.005$

$$d = -0.005 \pm \sqrt{\left\{25 \times 10^{-5} + 0.000515 \sqrt{\frac{87.9}{2400}}\right\}}$$

$$\pm \sqrt{\left\{2.5 \times 10^{-5} + 0.000515 \times \sqrt{3.662}\right\}}$$

$$\left\{2.5 \times 10^{-6} + 0.000515 \times 1.914\right\}$$

$$0.000025 + 0.000986$$

$$\pm \sqrt{0.00019} = \sqrt{19.19} \times 10^{-4} = 3.14 \times 10^{-2}$$

$$\pm 0.0314$$

$$= \pm 0.0264 \text{ cm}$$

$$= 0.0105 = \#31 \text{ B.W.G.}$$

1.2 ω per foot = 2000 feet = 0.6 lbs on each

Specific Gravity of 3 samples of Samarskite

Catalogue $\frac{478}{2000}$ Edison Collection.

6th June 90.

Weight of $\frac{478}{2000}$ in air		6·8655		
	- equivalent	5·5200		
		1·3455	= 5·103	
" small smaller piece	in air	1·1795		
	" H_2O	0·9485		
		0·2310	= 5·105	Mean 5·105 ± 0·0008 × sp. gr. of H_2O @ 25° C = 0·9970 = 5·090 × max. density of H_2O.
" " "	" air	1·3890		
		1·1170		
		·2720	= 5·106	

On the winding of a Phonoplex coil which shall take only half the present current while retaining the same inductance.

The dimensions of a #2 standard coil see book II p 101

$l = 9.9 \quad x = 6.15 \quad y = 2.15$

Area $29.7057 - 3.6305 = \text{Diff } 26.0752$.

Vol $= 26.075 \times 9.9 = 258$.

The thickness of silk is 0.003" , 0.0075 cm. $= 7.5 \times 10^{-3}$

$\frac{l}{2} = 3.75 \times 10^{-3}$

$(\frac{l}{2})^2 = 14.06 \times 10^{-6} = 1.4 \times 10^{-5}$

0.000015

$$d = -0.0074 \pm \sqrt{\{0.000.02 \pm 15\sqrt{\frac{360}{13.7}}\}}$$

$\pm 15\sqrt{25.50}$

$\pm 15 \times 5.05 \times 10^{-3}$

$\sqrt{\quad + 7.724 \times 10^{-3}}$

$\sqrt{(7.724 \times 10^{-3})}$

$\sqrt{(77.24 \times 10^{-4})}$

8.8×10^{-2}

$+ 0.088$

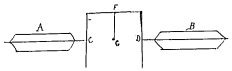
$= 0.0814$ cm.

$= 0.033''$

The nearest wire to this is #21 B.W.G. 0.032".

10.2 w of this @ 0.3074 lbs. per w = 3.135 lbs.

The wire used by Bergmann to fill the present coil #2 is #20 B.W.G. 0.035 and the resistance of this has to be doubled. the diam should be diminished to $\sqrt{\frac{1}{2}} \times 0.035 = 0.814 \times 0.035$ $= 0.029''$ Nearest number #21 B.+S.



The general equation of energy is as follows:—
Let $\mathcal{E}$ be the energy delivered from the supply line.

e_1 . . . . . to A (for friction)
e_2 . . . . . B (- - -)
η . . . . . B & A
ε . . . . . to the car

Then there are two cases
1st When the energy ε is less than e_1 the frictional losses magnetic, mechanical, and electrical in the motor and motor wheel.
2nd When ε is on the contrary greater than ε.

For the first case
$$\mathcal{E} = 2f + \varepsilon$$
$$e_1 = f + 2\varepsilon$$
$$e_2 = f - \varepsilon$$
$$\eta = 0$$

. . second case
$$\mathcal{E} = 2f + \varepsilon$$
$$e_1 = 2f + \varepsilon$$
$$e_2 = 0$$
$$\eta = \varepsilon - f$$

On the equations of motion for the new mitre gear system of car driving with two motors. (7)

The notation is the same as that on p 65.
In the two motors A and B.
Let w be the number of wires counted all round the armature
n_1, n_2 " - - - - revs. per sec: made by each
$\varphi_1 \varphi_2$ - - 8th phases through each.
ρ - - revs. of each armature (assumed equal)
E - - E.M.F. of supply (assumed fixed)
m - - tractive moment of the car round C.
μ - - moment of magnetic + mechanical friction
M, M_2 - - - of work on motor shafts
$\eta_1 \eta_2$ - - e.m.f. generated by each armature.

The two armatures are in parallel. The fields are excited separately.
Then 1st to reach the simplest case, assume $\rho = 0$ $\mu = 0$.

Then
$$2\pi n_1 M_1 = 2\pi n_2 M_2 + 2\pi \frac{(n_1 - n_2)}{2} m.$$
$$\text{but } M_1 = M_2 = M$$
$$2\pi n_1 M = 2\pi n_2 M + 2\pi \frac{(n_1 - n_2)}{2} m$$
$$\therefore m = 2M$$
$$2\pi n_1 M = E c_1$$
$$2\pi n_2 M = E c_2$$
$$\therefore E c_1 = E c_2 + 2\pi \frac{(n_1 - n_2)}{2} m$$

but these two terms on the right hand side must be equal

$$\therefore \frac{2\pi (n_1 - n_2) m}{2} = \frac{E c_2}{2}$$

Or the work done on the car will be half the energy absorbed by the motor, and the current in the dynamo will be half the current in the motor. If the car takes 5 HP. to run it then the motor will be absorbing 10 HP the dynamo will be generating 5 HP, and the system will be absorbing 5 HP.

3rd case. Friction considered but no revs: in armatures $\rho = 0$ $\mu > 0$

$$2\pi n_1 (M_1 - \mu) = 2\pi n_2 (M_2 + \mu) + 2\pi \frac{(n_1 - n_2)}{2} m$$

(but $M_2 + \mu = M_1$) $\quad E c_1 = \left\{ E c_2 + 2\pi n_2 \mu \right\} + \left\{ 2\pi \frac{(n_1 - n_2)}{2} m \right\}$

the two at back terms are equal

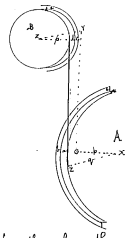
$$\therefore \text{in all cases } 2\pi \frac{(n_1 - n_2)}{2} m = E c_2 + 2\pi n_2 \mu$$

$$\therefore c_1 = c_2 + \frac{2\pi n_2 \mu}{E} + \frac{2\pi (n_1 - n_2) m}{2E}$$

Or the following motor will cease to absorb energy when the work done on the car is equal to its friction. It then becomes a friction clutch, + no current flows in its circuit but the energy supplied to the leading motor is still twice the energy required to drive the car. As the load on the car increases the following motor becomes a dynamo, and the above equation is still true.

Problem. Two pulleys run on axes fixed at right angles and a rope passes at right angles to each axis tangentially from the center of the face of one to the center of the face of the other. Determine the least free length of rope when the dimensions of the rims are given.

With the dimensions represented in the diagram, the rectangular coordinates of the opposed clips in the plane xz are



	X	Y	Z
For the wheel A	$(p-a)$	0	$(q+b)$
" " idler B	$(p+c)$	y	$(q-d)$

Then the coordinates of a point on the rim of the wheels at an elevation $Y = \bar{y}$ above the plane of xz are

For A	$(p-a)$	$\bar{y}$	$\sqrt{(q+b)^2-\bar{y}^2}$
" Idler B	$\sqrt{(p+c)^2-(y-\bar{y})^2}$	$\bar{y}$	$(q-d)$

Let the distance y be such that the rims then just touch. If the separation y or free length of the rope be made equal to this distance, we have the condition

$$\sqrt{\left\{(p-a)-\sqrt{(p+c)^2}\right\}^2+\left[\left\{\sqrt{(q+b)^2-\bar{y}^2}\right\}-(q-d)\right]^2} = 0$$

$$\text{or} \quad -(a+c)^2+\left\{\sqrt{(q+b)^2-\bar{y}^2}-(q-d)\right\}^2 = 0$$

$$\text{or} \quad \sqrt{(q+b)^2-y^2} = q-d \pm (a+c)$$

$$\therefore \quad (q+b)^2-y^2 = (q-f)^2 \quad \text{where } f = a+c+d$$

$$y^2 = (q+b)^2-(q-f)^2$$

$$y = \sqrt{(q+b)^2-(q-f)^2}$$

In a practical instance

$$a = 1$$
$$b = 0.6$$
$$c = 0.6$$
$$d = 1$$
$$q = 7.8$$
$$\therefore f = 2.6$$

$$y = \sqrt{(7.8+0.6)^2-(7.8-2.6)^2}$$
$$= \sqrt{8.4^2-5.2^2}$$
$$= \sqrt{70.56-27.04}$$
$$= \sqrt{43.52}$$
$$= 6.6$$

To determine the winding and dimensions of a quadripolar 18 kwt motor whose armature is to be 20" in diam, and whose peripheral speed is to be 4000 feet per min: the normal emf to be 15 volts generated.

The peripheral speed is 2000 cms per sec: and the diam. = 50.8 cms., so that the number of revs: per sec. = 12.53 or 750 per min.

Consequently $\Phi w = \frac{15}{12.5} \times 10^8 = 1.2 \times 10^8$

18 kilowatts @ 15 volts = 1200 amperes. The fall of potential in the armature must not exceed one volt, or the total res: must not exceed the $\frac{1}{1200}$th of one ohm.

Assume as a trial value 4" square to be the section of armature compressed copper wire. The iron will occupy 70 % of this space or 11.2 sq in = 72.24 sq. cms. If the normal induction be 13,000 this represents a value of Φ = 939,000 But making Φ = 1,000,000 normally, we can employ 120 compound bars round the armature.

If the radial depth of iron be 4.25" = 10.8 the % space 60 and induction 13,000 then $b = \frac{1,000,000}{\frac{10.8}{2.46} \times 13,000 \times 0.6} = 11.86$ cms = 4.68"

This breadth being too great, we may try 160 bars in which case $\Phi = \frac{1.2 \times 10^8}{1.5 \times 10^4} = 800,000$, and $b = 3.73" = 9.52$ cms.

If the thickness of the bars on top be 0.275" = 0.7 cm. below to 0.4" or 1 cm and on the sides be also 0.7 cm. then the resistance of the closed copper shell over round the wire would be

Upper and outer edge	9.5 cms long	$\pi \times 50$ broad	and 0.7 thick	$= \frac{9.5}{157.07}$	= 0.0836
Under - iron	19.0 -	$\pi \times 25$	-	- 1.0	$= \frac{19}{79 \times}$ = 0.1266
Two sides	12 -	35%	-	- 0.7	$= \frac{24}{77}$ = 0.3117
					0.5219

Total $0.5222 \times 18.00 = 9.40 \times 10^{-3}$ ω.

For 150 turns = $9.40 \times 10^{-3} \times 2.25 \times 10^{-4} = 21.15 \times 10^{-3}$

This ÷ 16 for a quadripolar machine = 1.32×10^{-3} = 0.0013 ω.

If the peripheral speed be increased to 5000 ft per min (2500 cms per sec) the revs: will be 15.67 per sec, or 940 per min.

Then $\Phi = \frac{1.5 \times 10^8}{1.567 \times 1.60 \times 10^3} = \frac{1.5}{2.508} \times 10^4 = 600,000$

For an induction density of 13,000.

$$\frac{13000 \times 9.5 \times \pi \times 0.60}{2} = 600,000$$

$$= \frac{6.0 \times 10^5}{6.0 \times 10^{-1} \times 1.3 \times 10^4 \times 9.5 \pi} = \frac{10^5}{1235 \times 10^3} = 81 \text{ AT}$$

$$= 3.19"$$

Each magnet will contribute 300,000 lines say with leakage 1,500,000 lines at a density (cast iron) of 7000 = 65 sq. cms = 9.1 cms = 3.6" diam.

Motor Calculations continued.

The reluctance of the air spaces will be as follows—
Each magnet cap will cover 67° of outer periphery = 1 radian circumference = $2\pi \times 25.4$ ∴ cap covers 25.4 cms. The breadth of iron will be 7.6 cms so that the area = 193 sq. cms. The entrefer here is 1 cm.

The area covered by the sides of the cap will be
$\pi(24.7^2 - 15.1^2) = 1901 - 179 = 1722$ sq. cms $- 40 \times 12.5$ (500)
$= 1222 \div 4 = 305$ sq. cms. The entrefer is here 1.0 cm.
The reluctance for air spaces is therefore

$$2\left(\frac{1.0}{6.0047}\right) + \frac{.2}{800} = 0.0025 \text{ limit.}$$

To force 1500,000 lines through this will require a M.M.F of
$2000 = 1.257 \times 1590$ or 800 A.T. on each limit, assuming negligible reluctance in the remainder of the circuit.

The external diameter of the magnets will be 11.7 cms the circumference 36.75. Their length is 12.5 = 25 for a pair the total surface on a pair is thus 920 sq. cms., and allowing 20 sq. cms per watt = 46 Watts, @ 15 volts = 3.0 amperes, or 6 amperes if all four are one side be in series.

The coiling space is on each core 12.5 x 4 cm.

~~Requirements for a Wire Armature of equal power.~~

The coiling space on each magnet core is $14\pi(7.25^2 - 2.75^2)$
$= 14 \times (53.9 - 7.9) = 14 \times 83 = 1162$ c.c.
The resistance is to be 1.25 ω each

$$d = 0.02 + \sqrt{0.00004 + 0.00153 \times \sqrt{\frac{1162}{1.25}} \times \sqrt{929.6} \times 30.5} + 0.004666$$

$$+ \sqrt{0.0471} = \sqrt{4.71 \times 10^{-2}}$$

$$+ 0.217$$

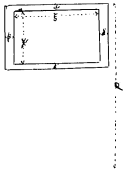
$$= 0.237 \text{ cm}$$

$$= 0.093'' \quad \text{#13 B.W.G. } 0.095''$$
$$\text{#11 B.S. } 0.091''$$

Taking 0.091. this has 20 lbs per ω, so that 1.25 ω = 25 lbs. and 8 spools will require 200 lbs. weight. This wire has 800 feet per ohm = 20000 feet in all. The mean diameter will be 0.4 feet, the mean circumference 1.25 feet, and the number of turns $\frac{20000}{1.25} = 16,000$. $= \frac{48000}{8}$ A.T. = 6000 A.T.

This exciting power will really be increased by if the diameter of external winding be reduced to 1.5 above iron and the weight on all the fields be reduced 120 lbs. = 15 lbs on each. All in series this will represent for $\frac{5\omega}{8} = 0.625\omega$ each = 0.042 ω per lb. = #13 B.W.G. 0.095". This wire has 874 feet per ω so that it has 546 feet on each spool. = 410 turns. = 12 ohms
= 2500.

With 160 lbs. weight on all in series for 5 ω = 32 lbs. per ohm = #10 B.S. wire. 0.102". = 20 lbs on each core @ 31.8 feet = 636 feet = 470 turns = 1410 A.T. = 2820 exciting power 3530 m.m.F.
60 turns per layer x 8 layers.



To commence with an approximation to the best value for w

let $\xi = \nu\psi$ and $a = \lambda\beta$

Then (10) becomes $$\frac{\nu\psi}{\lambda\beta} + \frac{\psi}{\beta} = \frac{\pi p^2 K r \rho_m}{\sigma w^2} \qquad (12)$$

and (11) $$\nu\psi w = \frac{\varepsilon\, 10^8}{2 n w u b} \qquad (13)$$

$$\frac{\nu\psi\beta}{\left(1+\frac{\nu}{\lambda}\right)} = \frac{\varepsilon\, 10^8}{2 n w u b} \times \frac{\sigma w^2}{\pi p^2 K r \rho_m} \qquad (14)$$

$$w = \frac{\nu\psi\beta\lambda}{\lambda+\nu} \times \frac{2\pi p^2 K r \rho_m\, n w u b}{\sigma\, \varepsilon\, 10^8} \qquad (15)$$

Formulae useful in the design of Motors.

Let e be the e.m.f. required from the motor at no load.
" r " " res. (ω) of the armature between brushes.
" q " " coefficient of e forming the maximum permissible drop at full load.
" p " " number of poles in the machine
" ρ_m " " res. (ω) of the ending space of armature considered as one turn.
" n " " number of wires or bars counted all round.
" n " " number of revs. per second.
" K " " coeff. of useful space occupied in the winding, after insulation &c.
" u " " coeff. of useful work in the armature space.
" Φ " " total flux through each pole head into the machine $\times 10^8$
" a " " breadth above of the conductor
" β " " " on one side ..
" γ " " " below ..
" δ " " " on the other side ..
" ξ " " " breadth of iron space
" ψ " " " depth " " " radially.
" ρ " " " ext. rad. of the armature
" J " " ~~strength~~ typ of the machine in watts at full load
" c " " current in " " (amperes) " " "

The first consideration is the power. This is generally determined by the drop, for if the drop at full load be not great the heating will not be excessive. Hence

$$c = \frac{J}{\varepsilon - qe} \qquad (1)$$

$$\cancel{\frac{\sigma J}{\varepsilon - qe} = q(\varepsilon)} \quad \therefore \frac{Jr}{\varepsilon(1-q)} = qe \qquad (2)$$

$$r = \frac{qe^2(1-q)}{J} \qquad (3)$$

To close approximation $$t_0 = \frac{\sigma}{2\pi}\left[\left\{\frac{\xi + \frac{(\beta+\gamma)}{2}}{a\rho}\right\} + \left\{\frac{\xi + \frac{(\delta+\delta)}{2}}{\gamma(\rho-\psi)}\right\} + \left\{\frac{\psi + \frac{(a+\frac{\gamma}{2})}{\delta(\rho-\frac{\xi}{2})}\right\} + \left\{\frac{\psi + \frac{(a+\frac{\gamma}{2})}{\beta(\rho-\frac{\xi}{2})}\right\}\right] \qquad (4)$$

σ = resistivity of copper (ω)

$$\therefore r = \frac{\sigma w^2}{2\pi K p^2 (X)} \qquad r = \frac{r_0 w^2}{p K} \qquad r_0 = \frac{\sigma p^2 K}{w^2} \qquad (5)$$

Also $$\varepsilon = \Phi n w \qquad (6)$$

and if Φ is the normal working induction, $$\Phi \times 10^8 = a\xi\psi b \qquad (7)$$

Less accurately (4) may be written $$r_0 = \frac{\sigma}{2\pi\rho_m}\left\{\xi\left(\frac{1}{a} + \frac{1}{\gamma}\right) + \psi\left(\frac{1}{\delta} + \frac{1}{\beta}\right)\right\} \qquad (8)$$

where $\rho_m = \left(\rho - \frac{\psi}{2}\right)$ and if $\left\{\begin{matrix}\alpha = \gamma \\ \beta = \delta\end{matrix}\right\}$ $$r_0 = \frac{\sigma}{2\pi\rho_m}\left\{\frac{\xi}{a} + \frac{\psi}{\beta}\right\} \qquad (9)$$

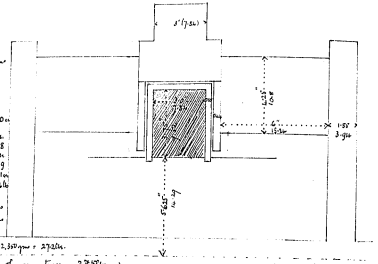
roughly $$\therefore \frac{\xi}{a} + \frac{\psi}{\beta} = \frac{\pi p^2 K r \rho_m}{\sigma w^2} \qquad (10)$$

and $$\xi\psi = \frac{\varepsilon \times 10^8}{2 n w u b} \qquad (11)$$

Generally a motor is designed with given or assumed values of ρ, n, ε and J. From these we can select a trial value of w. This gives by equation 11 the cross section of armature body $\xi\psi$. The ratio of ξ to ψ will generally be suggested by mechanical considerations and by the position of the magnets. Thus ξ and ψ are found. Suitable trial values of a and β must now be determined which will satisfy the approximate relation (10) the entafer being kept in view. The more accurate equations (4) + (5) must then be satisfied. If these will not enable convenient values to be obtained another value of w must be tried in (11). Equation (15) gives a preliminary value of w in terms of ψ and β.

Section through magnet poles of quadripolar motor

1/4

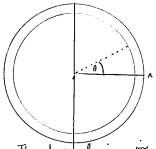


Volume of iron core
space 5750 c.c.
@ sp.g. 4.9 = 28,190 gms
= 62 lbs.

160 bars each 65 oz
Total 65 lbs.
Vol. of copper in coils 46680 cc
= 411.9 lbs. lbs.
Total copper in coils 456.8
Apparent wire 8.32 = 16.64
Diam. of core 10.7 wire 8.9
length 15.55 vol. 1371 cc
Mass 10,190 gms = 22.46
8 coils = 180.8 lbs
Frame approximate dimensions
3.94 × 2.22 × 7.5 = 65,722 cc
= 145 lbs 2 = 390 lbs.
Shaft 3 × 2.25 × 20.25 × 8 = 12,350 gms = 27.24 lb.

Total calculated weight of armature 378 lbs.
- - - -

On the number of turns of binding wire needed on the periphery of an armature to overcome the centrifugal force of the bars, assuming these to be held in contact entirely by the tension of the wire binding.



Let the figure represent a section of the armature by a plane at right angles to the axis. Let n be the number of bars

m . . mass of each bar

M = mn . total mass.

v = velocity of the c.i. of bar.

ω = ang. vel. . . . . .

Then consider the forces resolved parallel to OA

The bar lying in plane OA exerts a pull $\frac{mv^2}{r}$

. . making an angle $+\frac{2\pi}{n}$ . . . $\frac{mv^2}{r}\cos\left(\frac{2\pi}{n}\right)$

. . . . . $+\frac{4\pi}{n}$ (2) . . . $\frac{mv^2}{r}\cos\left(\frac{4\pi}{n}\right)$

. . . . . $\frac{2\pi}{n}\times\frac{n}{2}$ . . . $\frac{mv^2}{r}\cos\left(\frac{\pi}{2}\right)$

and the bars making similar negative angles give an equal pull each to each, in the same direction.

$$\text{Total pull} = 2\frac{mv^2}{r}\left(\cos\frac{2\pi}{n} + \cos\frac{4\pi}{n} + \cos\frac{6\pi}{n} + \quad + \cos\frac{n}{2}\frac{2\pi}{n}\right)$$

This is a well known trigonometrical series, always capable of definite arithmetical solution. For most purposes however it will be sufficient to consider $n = \infty$

Then the force exerted by an element of the ring $+d\theta$ will be

$$df = \frac{M d\theta}{2\pi}\frac{r^2\omega^2}{r}\cos\theta = \frac{M d\theta}{2\pi}r\omega^2\cos\theta$$

The total force acting normal to the plane BOC will be

$$F = \frac{Mr\omega^2}{2\pi}\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}}\cos\theta\, d\theta = \frac{Mr\omega^2}{\pi} = \frac{1}{\pi}\frac{Mv^2}{r}$$

Consequently the tension on the binding wire due to centrifugal force will be $\frac{1}{\pi}$ the centrifugal force due to the whole weight of the bars collected at one point. It will therefore be sufficient to make the power of the binding wire $\frac{Mv^2}{r}$ or $\left(\frac{Mv^2}{g\,r}\right)$ lbs. tension, v being expressed in ft per sec. r in feet $g = 32$ and M in lbs. mass

On the Mathematical laws of the Impact of moving bodies, compatible with Newton's coefficient of restitution.

Let M and $M_1 = \alpha M$ be the masses of impinger(I) and impinge(J) respectively
V - $V_1 = \beta V$ - - initl velocities " " " "
v - - common - - - - - -
U - U_1 - - final - - - - - -
ε - - coefficient of restitution.

Then the following conditions will hold,

Body	Velocity	Mass	Momentum	Change of Momentum	Kinetic Energy	Change of energy	Total energy	Change of totl
I	V	M	MV	-	$\frac{MV^2}{2}$		$\frac{MV^2+M_1V_1^2}{2}$	-
J	V'	M'	$M'V'$	-	$\frac{M'V'^2}{2}$	-	$\frac{MV^2}{2}(1+\alpha\beta^2)$	.
	βV	αM	$MV\alpha\beta$	-	$\frac{MV^2}{2}(\alpha\beta^2)$	-		
I	v	M	Mv	$-M(V-v)$	$\frac{Mv^2}{2}$	$-\frac{M}{2}(V^2-v^2)$		
	$V\left(\frac{1+\alpha\beta}{1+\alpha}\right)$		$MV\left(\frac{1+\alpha\beta}{1+\alpha}\right)$	$-M\left\{V\left(1-\frac{1+\alpha\beta}{1+\alpha}\right)\right\}$	$\frac{MV^2}{2}\left(\frac{1+\alpha\beta}{1+\alpha}\right)^2$	$-\frac{MV^2}{2}\left\{1-\left(\frac{1+\alpha\beta}{1+\alpha}\right)^2\right\}$	$\frac{MV^2}{2}\frac{(1+\alpha\beta)^2}{1+\alpha}$	$\frac{MV^2}{2}\frac{\alpha(1-\beta)}{1+\alpha}$
				$-MV\left(\frac{\alpha(1-\beta)}{1+\alpha}\right)$	$\frac{MV^2}{2}\left(\frac{1+\alpha\beta}{1+\alpha}\right)^2$	$-\frac{MV^2}{2}\left\{1-\left(\frac{1+\alpha\beta}{1+\alpha}\right)^2\right\}$		
J	v	M'	$M'v$	$-M_1(V_1-v)$	$\frac{M_1v^2}{2}$	$-\frac{M_1}{2}(V_1^2-v^2)$		
	$V\left(\frac{1+\alpha\beta}{1+\alpha}\right)$		$MV\alpha\left(\frac{1+\alpha\beta}{1+\alpha}\right)$	$-\alpha MV\left(\frac{1-\beta}{1+\alpha}\right)$	$\frac{MV^2}{2}\alpha\left(\frac{1+\alpha\beta}{1+\alpha}\right)^2$	$-\frac{\alpha MV^2}{2}\left\{\beta^2-\left(\frac{1+\alpha\beta}{1+\alpha}\right)^2\right\}$		
I	U	M	$MV\left\{\frac{1+\alpha\beta-\varepsilon\alpha(1-\beta)}{1+\alpha}\right\}$	$-M(v-U)$	$\frac{MU^2}{2}$	$-\frac{M}{2}(V^2-U^2)$		
	$V\left\{\frac{1+\alpha\beta-\varepsilon\alpha(1-\beta)}{1+\alpha}\right\}$			$MV\left\{\frac{1+\alpha\beta-\varepsilon\alpha(1-\beta)}{1+\alpha}\right\}$	$\frac{MV^2}{2}\left\{\frac{1+\alpha\beta-\varepsilon\alpha(1-\beta)}{1+\alpha}\right\}^2$	$-\frac{MV^2}{2}\left[1-\frac{\{1+\alpha\beta-\varepsilon\alpha(1-\beta)\}^2}{1+\alpha}\right]$		
J	U'	M'	$M'U'$	$-M(v-U')$	$\frac{M'U'^2}{2}$	$-\frac{M'}{2}(V_1^2-U_1^2)$	$\frac{MV^2}{2}\left(\phi^2+\alpha\psi^2\right)$ where $\phi = \left\{\frac{1+\alpha\beta-\varepsilon\alpha(1-\beta)}{1+\alpha}\right\}$ and $\psi = \left\{\frac{\alpha+\beta+\varepsilon\alpha(1-\beta)}{1+\alpha}\right\}$	$\frac{MV^2}{2}\left(\phi^2+\alpha\psi^2-\beta^2\right)$
	$\left\{\frac{\alpha+\beta-\varepsilon\alpha(1-\beta)}{1+\alpha}\right\}$		$MV\left\{\frac{\alpha+\beta-\varepsilon\alpha(1-\beta)}{1+\alpha}\right\}$	$\varepsilon MV\left\{\frac{\alpha-(1-\beta)}{1+\alpha}\right\}$	$\frac{\alpha MV^2}{2}\left\{\frac{\alpha+\beta+\varepsilon\alpha(1-\beta)}{1+\alpha}\right\}^2$	$-\frac{M'}{2}(\alpha\beta)\left\{\beta^2-\psi^2\right\}$ $\therefore \phi^2 = \left\{\frac{\alpha+\beta+\varepsilon\alpha(1-\beta)}{1+\alpha}\right\}^2$		

These expressions are capable of great simplification under special conditions. For example as the simplest case let $M = M'$ and $\varepsilon = 1$ $\therefore \alpha = 1$
The change in kinetic energy then becomes 0.
In the next simplest case let $\varepsilon = 1$ but $M \geqq M'$.
Then the change in kinetic energy of the system becomes $2MV^2\frac{\alpha}{(1+\alpha)^2}(1-\beta)(\alpha^2-1)$
If $\beta = \infty$ $\varepsilon \frac{MV^2}{2}\frac{4\alpha(\alpha^2-1)}{(1+\alpha)^2}$

Angle of solar dispersion 21. VI. 90 $\tan^{-1}\frac{1}{30'} = \frac{1}{360} = 0.00277 = 0°\,9'.20''$

Dimensions and Data of Copper wire Helix after rewinding
May 1890.

1st layer	103 turns		9th layer	103 turns.		Length overall	16.25"
2nd	103	"	10th	103	"	Outer flange	15.25
3rd	103	"	11th	102	"	Int. diam.	4.58
4th	104	"	12th	102		Out. "	5.25
5th	102	"	13th	102		Flange "	10.4
6th	102	"	14th	102		Layers	17
7th	103	"	15th	102		Turns	1742
8th	103	"	16th	101		Turns per cm =	114.2
			17th	102.			

Test of the magnetic susceptibility of different specimens of ore.
June 22nd 1890.

Five parallelopipeds were ground and faced very fairly true from different samples of ore. The above coil was situated at right angles to the magnetic axis of the Gauss magnetometer and distant 121 cms. The scale was distant 262 cms. A second solenoid was placed on the opposite side of the needle about 80 distant, and served to annul the effect of the magnetising solenoid. The current in the latter was $0.075 \times 0.195 = 3.46$ ampères, the field $= 1.257 \times 3.46 \times 114.2 = 497$ units.

The deflections produced were when the specimens were placed in the coil axis

No 1.	1.0	Moment 608.5 Vol.
2	0.05	
3	0.0	
4	0.5	
5	0	

$$M = \frac{d}{262} \times 0.18 \times \frac{(121)^3}{2} = d \times 608.5$$

No. of Sample	Weight in air	Weight in Water	Loss. or vol.	sp. g.	% assay of Fe_2O_3	% Iron	Deflection	Moment	Intensity of magnetisation	K.ot	H
1	84.27	64.85	19.42	4.34	71	51.4	1.0	608.5	31.3	0.063	497
2	26.81	17.96	8.85	3.03	16	11.6	0.05	30.4	3.435	0.0069	
3	9.025	5.97	3.055	2.95	20	14.5	0	0	—		
4	60.32	45.62	14.70	4.10	94	68.1	0.5	304	20.68	0.042	
5	64.34	46.72	17.62	3.65	1	0.7	0	0	—		

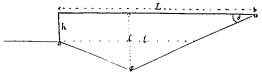
Particulars of the two Electro dynamometers

No. 1.	a	coil	# 19. BWG	D.C.C. #0.042"	9	layers	of 22	turns each.	198 turns
	b	"	# 13	" " " #0.095"	2	"	" 10	" "	20
No 2	a	"	# 23 BWG	D.S.C. 0.025"	15	"	" 36	" "	540
	b	"	# 6	D.C.C. 0.203"	1	"	" 5	" "	5

Mean Length 50 μ
" Breadth of front 4.2 μ } 7. III. 90
" Length " 5.5 μ.

Problem.

A wire is drawn taut over two small freely running but fixed pulleys and under a third intermediate free and weighted pulley in the same vertical plane. Determine the strain at any given position of the intermediate pulley when the two others are at known positions not on the same level.



(1) $\frac{W}{2} = S \sin\theta$

(2) $l = L - h\cot\theta$

(3) $\frac{2(l-h)}{l} = \tan\theta$

$\therefore \quad \frac{2(l-h)}{L - h\cot\theta} = \tan\theta \qquad \therefore \quad 2(l-h) = L\tan\theta - h$

$\therefore (2d \mp h)\sqrt{1-\sin^2\theta} = L\sin\theta$

$(2d \mp h)^2(1-\sin^2\theta) = L^2\sin^2\theta$

$\sin^2\theta\{L^2 + (2d \mp h)^2\} = (2d \mp h)^2$

$$\sin\theta = \frac{2d \mp h}{\sqrt{\{L^2 + (2d \mp h)^2\}}}$$

and $$S = \frac{W}{2}\,\frac{\sqrt{\{L^2 + (2d \mp h)^2\}}}{2d \mp h}$$

If $h = 0$ this becomes

$$S = \frac{W}{2}\,\frac{\sqrt{\left(\frac{L}{2}\right)^2 + d^2}}{d}$$

Problem.

To determine the torque of a multipolar motor of gramme type.

Let p be the number of poles.

ϕ - - flux through each polar surface. abs. meas.

c - - total current through the armature abs. m.

w - - number of wire or bars counted all round.

h - - strength of field at any point. abs.

r - - equivalent radius of polar head or of armature

b - - breadth of the armature cms.

Then at any part of the armature the $\frac{c}{p}$

The current in any angle $\Delta\theta$ of the armature is :-

$$\Delta c = \frac{\Delta\theta}{2\pi}\,\frac{wc}{p}$$

the attraction on this will be $b\,\Delta c\,h$ tangentially

The total tangential attraction round each segment of the circle will be $b\,h\,\frac{2\pi}{p}\,\frac{wc}{2\pi p} = \frac{b\,h\,wc}{p^2}$ where h is the mean field

But $\phi = b\,h\,\frac{2\pi r}{p}$

$\therefore$ attraction over each segment $= \frac{wc\phi}{2\pi p r}$

and total attraction all round circle $= \frac{wc\phi}{2\pi r}$

the moment at unit radius is thus $\frac{wc\phi}{2\pi}$ and is independent of the number of poles.

Test of a sample of overhead ~~Silicon~~ Bronze Trolley wire for the Sprague Railway Co.

This wire 100 feet in length was received at the Laboratory on the 26th inst. It was required to test it for tensile strength, ductility, conductivity, and accuracy to gauge.

To ascertain its breaking strain a short length was taken to Messrs Morton of N.Y. chain maker, but as their machine only indicates up to 2000 lbs. it became impossible to try it thus, and arrangements were made to test it at the Laboratory instead.

The wire was secured to one of the beams of the travelling crane, and a pulley was lashed opposite to the other and just beneath it. A heavy weight was lifted in the dip between these two point of support dynamometer fashion, and the weight raised by chain block and fall until the wire parted. This occurred twice following at the hauling nip at almost the same strain.

In these cases $L = 184$ $h = 13.0$ $d = 40$ (1) $W = 1866$.
39.5 (2)

$$S_1 = \frac{W}{2}\,\frac{\sqrt{184^2 + 67^2}}{67} = \frac{W}{2}\,\frac{\sqrt{33856 + 4,489}}{67} = \frac{W}{2}\,\frac{\sqrt{38,345}}{67} = \frac{W}{2} \times \frac{196}{67}$$

$$S_2 = \frac{W}{2}\,\frac{\sqrt{184^2 + 66^2}}{66} = \frac{W}{2}\,\frac{\sqrt{33,856 + 4,356}}{66} = \frac{W}{2}\,\frac{\sqrt{38,212}}{66} = \frac{W}{2} \times \frac{195.5}{66}$$

$W = 1866$ lbs $S_1 = 933 \times 2.926 = 2.73$ tons wt. $= 61,300$ lbs. per sq. in. $= 4295$ kgms per sq. cm.

$S_2 = 933 \times 2.962 = 2.764$ . . . $= 61,900$ . . . . $= 4352$ . . . .

Tests of Sprague Railroad Wire contd.

The diameter of the wire was determined by laying 78 feet along the floor and measuring with a Brown & Sharpe micrometer screw to 1/10,000" at every 3 feet. The measurements were in one or two instances checked by other micrometers of the same firm.

No. of Obs.	Measurement	Mean x	v (Z = m)	v^2	Σv^2		Σv		
1	0.2385	0.2385"	0						
2	0.2394		−0.0009	81×10^{-8}	741×10^{-8}				
3	0.2385		0				0.0101		
4	0.2386		−0.0001	1	$\sqrt{20}$				
5	0.2387		−0.0002	4					
6	0.2387		−0.0002	4	27.22×10^{-4}				
7	0.2375		+0.0010	100	$= 0.002722$				
8	0.2386		−0.0001	1					
9	0.2386		−0.0001	1					
10	0.2390		−0.0005	25	$\sigma_1 = 0.000375$		$\sigma = 0.00035$		
11	0.2380		+0.0005	25					
12	0.2379		+0.0006	36	$\sigma_2 = 0.000675$		$\sigma_m = 0.000070$		
13	0.2388		−0.0003	9					
14	0.2390		−0.0005	25					
15	0.2382		+0.0003	9					
16	0.2385		0						
17	0.2397		−0.0012	144					
18	0.2385		0						
19	0.2393		−0.0008	64					
20	0.2384		+0.0001	1					
21	0.2380		+0.0005	25					
22	0.2381		+0.0004	16					
23	0.2373		+0.0012	144					
24	0.2380		+0.0005	25					
25	0.2386		−0.0001	1					

The mean diameter of the sample was thus $0.2385'' \pm 0.000075$ (0.03%)
$= 0.6058 \pm 0.00019$

The chances are 2 to 1 that as far as observations are concerned the diameter lies between 0.2384" and 0.2386", assuming the wire to be a true cylinder. The mean area is $0.04467 5'' \pm 0.0000253$ (0.056%)
$.28826 \pm 0.0001163$ sq. cms

The conductivity was measured by passing a current of about 9 amperes through a measured length of this wire in ct. with the standard grid and 0.01 comparing the terminal p.d. by differential galvanometer. Temp of air 24°C.

1st test. R. of G. 2738 ω each coil. $\left(\begin{matrix}2744.5\\2725.5\end{matrix}\right)$

775 ω added to grid = 3519.5 ω in grid ct

Res. of wire $\frac{2728.5}{3949.5}$ grid = 0.7742 grid. = $0.7742 \times 0.04913 = 0.03804\,\omega$

The length of wire between pressure wires was 2263.5 cms.

res. per cm $= \frac{3.8044 \times 10^{-2}}{2.2635 \times 10^{3}} = 1.681 \times 10^{-5}$ per sq. cm $= 4.8445 \times 10^{-6}$

$= 4.8445$ ab. w. legt.

Pure copper $= 1620$ @ 0°C. $\quad 1620\,(1 + 0.0388 \times 24) = 1620 \times 1.0931$

$= 1771$ @ 24°

% Conductivity $= \frac{1771 \times 100}{4.8445} = 0.3655$ $\quad$ or 36.55% of Matthiessen

8·7 feet weigh 1·5 lbs = 0·17241 lbs. per foot = 910·2 lbs. per mile of 5280 ft
250·5 cmc = 650·4 gms = 2·716 gms per cmc. = 4422 gms per c.c.

Ductility Test.

Two samples ten inches long received from complete burn before breaking. = 2·5" for one burn. $\frac{260}{2.5}$ = 104·0" per inch. = 1728" per foot.

Resume of Specific Conductivity Tests

No. of Test	Length tested	Compared with	Res. of Galvo	Balance	added to	Res. with Conductivity @ 24°C	Spec. Cond. Cm (from 0°C 1771 @24)	Mean Spec. Cond.	v	t_m
1	2263·5	0·004913	2724·5 / 2705·5	775 ω	0·004913	4834·5	0·3660		0·0005	
2	2264	0·004913	2724·5 / 2705·5	775 ω	"	4836	0·3662		0·0001	
3	1500	0·004913	2724·5 / 2705·5	2870 ω	"	4825	0·3670		0·0009	
4	1500	0·009833	2735 / 2735	4275 ω	wire	4845	0·3656	0·3661	0·0005	0·00013
5	750	0·009833	2735 / 2735	760 ω	"	4830	0·3660	(4837·5 Lab)	0·0001	0·036%
6	750	0·009833	2735 / 2735	770 ω	"	4843	0·3657		0·00014	
7	586·2	0·009833	2735 / 2735	0 ω	"	4835	0·3663		0·0002	
						Mean 4837			0·0027	

The mean resistivity being 4837 legal units $= 1.678 \times 10^{-5}$ " per cm.
$= 5.114 \times 10^{-10}$ " per foot
$= 2701$ " per mile of 5280 ft

Comparison of standard 0·01 ω and grid, the former being at 25·6°C the latter at 28°C.
Res. & Temp. of standard = 0·009833 ω Res. of G. 27400 ω
10,950 ω added to grid ct. with 8 amperes through main ct.
$= \frac{13,690}{27400} \times 0.009833 = 0.04913$ ω

2nd Test. Length tested 2264 ω R. of G. 2724·5 / 2705·5 775 ω added to grid

$$R_{cc} = \frac{2705.5}{2724.5 + 775} = \frac{2705}{3499.5} \times 0.04913 = 0.773 \times 0.04913 = 0.03755 \text{ ω}$$

$$= \frac{0.037985}{2264} = 1.678 \times 10^{-5} \text{ per cm} = 4.836 \times 10^{-6} \text{ per c.c.}$$

$= 4836$ abs. l. u. per c.c.

Matthiessen's std $= 1771$ - - - @ 24°C

$= 36.62\%$ 0·3662

3rd Test length tested 1500 R. of G. 2724·5 / 2705·5 2870 added to grid

$$R_{cc} = \frac{2705.5}{2724.5 + 2870} = \frac{2705.5}{5594.5} \times 0.04913 = 0.02511$$

$$= \frac{2.511}{1.5} \times 10^{-5} = 1.674 \times 10^{-5} \text{ per cm} = 4.825 \times 10^{-6} \text{ per c.c.}$$

Spec. Conductivity $= \frac{1771}{4825} = 0.367 = 36.7\%$

4th Test. Length tested 1500 R. of G. 2735 / 2735 4275 ω added to wire (0·01 ω)

$$R_{cc} = \frac{4275 + 2735}{2735} \times 0.009833 = 2.563 \times 0.009833 = 0.02521 \text{ ω}$$

$$= \frac{2.521 \times 10^{-5}}{1.5} = 1.681 \times 10^{-5} \text{ per cm} = 4.845 \times 10^{-6} \text{ per c.c.}$$

Spec. Conductivity $= \frac{1771}{4845} = 0.3656 = 36.56\%$

5th Test. Length 750 R. of G. 2735 / 2735 760 ω added to wire (0·01 ω)

$$R_{cc} = \frac{2735 + 760}{2735} \times 0.009833 = 1.278 \times 0.009833 = 0.01257 \text{ ω}$$

$$= \frac{1.257 \times 10^{-5}}{0.75} = 1.676 \times 10^{-5} \text{ per cm.} = 4.830 \times 10^{-6} \text{ per c.c.}$$

Spec. Conductivity $= \frac{1771}{4830} = 0.366 = 36.6\%$

6th Test length another 750 R. of G. 2735 / 2735 770 ω added to wire (0·01 ω)

$$R_{cc} = \frac{2735 + 770}{2735} \times 0.009833 = 1.2815 \times 0.009833 = 0.01260 \text{ ω}$$

$$= \frac{1.260 \times 10^{-5}}{0.75} = 1.6805 \times 10^{-5} \text{ per cm} = 4.843 \times 10^{-6} \text{ per c.c.}$$

Spec. Conductivity $= \frac{1771}{4843} = 0.3657 = 36.57\%$

7th Test length 586·2 R. of G. 2735 / 2735 0·01 ω balance wire

Res of wire $= 0.009833$ ω

$$= \frac{0.009833}{586.2} = 1.678 \times 10^{-5} \text{ per cm.} = 4.835 \times 10^{-6} \text{ per c.c.}$$

Spec. Conductivity $= \frac{1771}{4835} = 36.63\%$ 0·3663

On the number of discs in a Wirt Lightning Protector to carry off a ⅝" spark.

Assuming what is true for plane parallel surfaces that the breaking voltage is 30,700 with 325 volts for polarisation.

Then a ⅝" spark $= \left(\frac{2.54}{8} \times 30{,}700 + 325\right)$ volts $= 10{,}073$ volts.

And if the thickness of each disk be d cms.

$$10{,}073 = nd \times 30{,}700 + n \times 325$$

$$\text{or } n = \frac{10{,}073}{30{,}700\, d + 325}$$

d is stated to be $0.03'' = 0.075$

$$n = \frac{10{,}073}{2300 + 325}$$

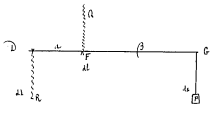
$$= 3.84 \quad \text{say } 4.$$

On the condition of ~~double~~ mixed levers.

If D F G be a lever with a force applied at P and a fulcrum at F it is of the first order. If D be the fulcrum it will be of the second order. Considering each of these points as capable of moving when sufficient force is applied to them, the condition of acting as 1st order is $Q > P + R$

and " " " " 3rd " " $R > P\frac{\alpha}{\alpha+\beta}$

It is possible however for both forces to be adjusted into capability of independent but coincident motion.



These conditions are

$$P\,ds - Q\,dl - R\,d\lambda = 0 \qquad (1)$$

$$ds - \frac{\alpha+\beta}{\alpha}\,dl - \frac{\beta}{\alpha}\,d\lambda = 0 \qquad (2)$$

Substituting the values of ds from (2) in (1)

$$P\left(\frac{\alpha+\beta}{\alpha}\right)dl + P\frac{\beta}{\alpha}\,d\lambda = Q\,dl + R\,d\lambda$$

Equating coefficients of dl & $d\lambda$

$$\therefore Q = P\left(\frac{\alpha+\beta}{\alpha}\right) \qquad R = P\frac{\beta}{\alpha}$$

$$\text{or } Q = P + R \qquad = P + P\frac{\beta}{\alpha}$$

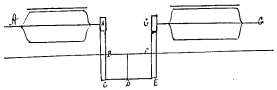
$$\text{Also } dl = \frac{ds}{2}\cdot\frac{\alpha}{\alpha+\beta} \qquad d\lambda = \frac{ds}{2}\cdot\frac{\alpha}{\beta}$$

The energy delivered is $P\frac{ds}{2}$ to Q

" " $P\frac{ds}{2}$ " R

so that while P and Q retain compatible values the energy absorbed at G will be equally divided between Q and R.

Differential bevel gear is a mixed lever. The moment of the working ~~dynamo~~ motor being M and that of the dynamo being $D = \frac{M}{\beta}$, the shaft at Q is $\frac{M}{\alpha}$ and if this be insufficient to start the car, the motor & dynamo must generate more power until ~~Q = M~~ $M = \frac{\beta Q}{\alpha}$



On the equations of motion of the differential bevel-wheel (90

Equations continued from page 77.

If ε be the emf. of constant supply at motor terminals
n_1, n_2 - - number of revs. per sec.
φ_1, φ_2 - - fluxes
r - - velocity ratio of the gears AB and GF
t - - no. of each armature
w - - no. of wires - - - .

Then the current in A is $\dfrac{\varepsilon - n_1\varphi_1^{-1}w}{r}$

- energy - - - $\dfrac{n_1\varphi_1^{-1}w\,(\varepsilon - n_1\varphi_1^{-1}w)}{r}$
- moment at A - $\dfrac{\varepsilon - n_1\varphi_1^{-1}w}{r}\cdot\dfrac{\varphi_1 w}{2\pi}$
- - - B - $\dfrac{\varepsilon - n_1\varphi_1^{-1}w}{r}\cdot\dfrac{\rho\varphi_1 w}{2\pi}$.
- pressure P_C - C - $\dfrac{\varepsilon - n_1\varphi_1^{-1}w}{r}\cdot\dfrac{r\varphi_1 w}{2\pi\rho}$ where ρ is rad: of diff. wheel
- - P_E - E - $\dfrac{\varepsilon - n_2\varphi_2^{-1}w}{r}\cdot\dfrac{r\varphi_2 w}{2\pi\rho}$

and since $P_D = P_E$ we have $\varphi_1(\varepsilon - n_1\varphi_1^{-1}w) = \varphi_2(\varepsilon - n_2\varphi_2^{-1}w)$

or if $\beta = \dfrac{\varphi_2}{\varphi_1}$ $\quad \dfrac{\varphi_2}{\varphi_1} - \beta = \dfrac{S_1}{S_2}$ where S_1 is the resistance drop in A
- S_2 - - - - - B.

the ratio of the fluxes must be in the ratio of the pickmil drops.

Pressure at D $= \dfrac{C}{\rho}$ - where C is the moment of reaction at D

$$= \frac{2(\varepsilon - n_1\varphi_1^{-1}w)}{r}\cdot\frac{r\varphi_1 w}{2\pi\rho}$$

$$\therefore\ C = \frac{2(\varepsilon - n_1\varphi_1^{-1}w)}{r}\cdot\frac{r\varphi_1 w}{2\pi}$$

$$= \frac{2\varphi_1 r\varphi_1 w}{2\pi}$$

$$= 2\times \text{torque of motor.}$$

Rough Determination of the amount of gold in a matrix of quartz.

Weight of specimen of same stone without gold :— 11.q. 210 gr = 6335 grains
less 7. 460 — 3523
2812

in water 11q 450 . 5262
less 7. 460 . 3523
1739

sp. g. = 1073 ÷ 2812 = 2.621

Weight of specimen containing gold. 3lbs. 9.sq 40 gr. = 25196
less 7 100 — 3160
22,036

in water 2 lb. 7q. 310 gr 17,372
7 100 — 3160
14212

$7814 \times 0.06448 = 506.4$

sp. g. = 22036 ÷ 7814 = 2.819

$2.621\,(506.4 - x) + 19.3\,x = 506.4 \times 2.819$
$16.679\,x = 506.4\,(2.819 - 2.621)$
$= 506.4 \times 0.198$
$= 100.3$
$x = 5.973$ c.c. $\times 19.3 = 115.3$ grs of gold
$= 4067$ oz. of gold.

Meteorological Records.

Date		Barometer Inches	Barometer Corr.	Temp.	Barometer Corrected 0° F.	Thermometer Max.	Thermometer Min.	Thermometer Rng.	Thermometer Wet	Rainfall 24 hours	Wind	Remarks
July	5th	30.050	76.32			83	55°	79	77	0.10	N.W.	Fair. Clearing
	6	29.840	75.51	76.0	29.713	86	56	78	78	—	N.	Fine
	7	29.845	75.82	78°	29.787	78°	62°	89°	77°	—	S	Fair
	8	29.733	75.53	80°	29.677	101°	60°	80°	85°	—	S	Fair
	9	29.607	75.24	82	29.457	86	75°	81°	76	—	N.W.	Fair
	10	29.847	75.84	83°	29.724	89	65°	67°	63°	—	N.W.	Fair
	11	29.947	76.07	83°	29.824	80°	56°	73°	67°	—	N.W.	Fair
	12	29.883	75.91	75°	29.734	70°	57°	78°	75°	—	S	Fair
	13	29.841	75.82	72°	29.751	89°	63°	68°	65°	.075	S.E.	Overcast. Rain
	14	29.893	75.88	70°	29.762	86°	56°	77°	70°	—	S	Fair. Overcast
	15	29.834	75.79	73°	29.710	85°	67°	83°	80°	—	S	Fair
	16	29.871	75.84	80°	29.722	76°	70°	85°	80°		W	Fair
	17	29.725	75.50	83°	29.590	88°	72°	80°	83°		S	Fair
	18	29.739	75.59	76°	29.621	78°	68°	73°	69°	.58	N.W.	Fair
	19	29.731	75.53	74°	29.605	80°	55°	75°	68°		S.W.	Fair
	20											
	21											
	22	29.895	76.09	72°	29.826	90	54	76°	70°		N.W.	Fair
	23	29.964	76.15	72°	29.894	91°	52°	75°	71°		N.W.	Fair
	24	29.871	75.88	73°	29.798	78	63	76	73°		S.W.	Overcast. Cloudy
	25	29.739	75.53	75°	29.614	78	70	73	70	.90	S.W.	Rainy
	26	29.685	75.56	74°	29.517	78	70	72	76	.295	S	Overcast
	27	29.871	75.88	70°	29.734	87	67	83°	75		S	Overcast.
	28	29.977	76.07	80°	29.833	98	67	83	79		S	Fair
	29	29.971	76.15	74°	29.831	84	68	74	72	.55	S.W.	Overcast
	30	29.893	75.93	77°	29.752	94	69	84	82	.12	S	Overcast
	31	29.785	75.56	85°	29.579	96°	75°	89°	83		S	Fair
Aug	1	29.785	75.60	89°	29.639	93°	75°	85°	83°		S.W.	Fair. Overcast.
	2	29.957	76.04	82°	29.779	90	72	83°	79°		C	Overcast
	3											
	4	29.917	76.00	80°	29.773	87	65	83°	84	.02	S	Fair
	5	29.921	76.01	82°	29.771	94°	70°	85°	82°		S	Fair. Overcast
	6	29.881	75.90	80°	29.737	87°	70°	82°	78°	.34	S.W.	Fair. Overcast
	7	29.893	75.79	79°	29.752	91°	66°	86°	75°		S.W	Fair
	8	29.867	75.75	76°	29.735	85°	68°	77°	74°		SW	Overcast
	9	29.713	75.48	72°	29.592	75°	65°	69°	68°	.07	S	Overcast Rain
	10	29.525	75.00	75°	29.396	91°	63°	82°	77°		S	Fair. Overcast
	11	29.635	75.25	70°	29.523	85°	56°	69°	64°	.04	W	Overcast
	12	29.741	75.51	70°	29.729	74°	63°	71°	68°		N.	Fair
	13	29.895	75.94	70°	29.771	75°	61°	71°	68°	.16	N	Fair. Overcast
	14	29.785	75.66	72°	29.665	80°	61°	75°	68°		SW	Fair
	15	29.957	76.09	73°	29.864	86°	60°	72°	66°		S	Fair
Omitted	16	29.992	76.05	75°	29.873	83°	65°	82°	75°		S	Fair
	17	29.960	76.10	70°	29.831	85°	69°	74°	73°	.502	W	Rainy. Clearing
	18	29.930	76.03	72°	29.810	73°	66°	71°	70°		S	Rainy. Overcast.
	19	29.886	76.01	75°	29.757	76°	69°	78°	74°	.61	W	Fair
	20											
	21	29.862	76.02	75°	29.733	82°	65°	75°	73		S	Overcast.
	22	29.712	76.07	75°	29.583	88°	65°	77°	74°	.275	S	Fair
	23	29.744	75.88	69	29.633	80°	58°	65°	64		S	Fair
	24	29.826	75.91	63°	29.791	66°	49°	65°	65°			Overcast.
	25	29.820	75.85	67°	29.715	74°	47°	70°	64°			Fair
	26	29.728	75.58	77°	29.633	77°	60°	76°	73°			Fair
	27	29.526	75.03	74°	29.400	79°	69°	67°	72°	.950	S	Rainy
	28	29.750	76.02	74°	29.624	84°	60	71°	68			Overcast.
	29	29.721	75.85	74°	29.595	79°	61	79	72°		NW	Fair
	30	29.588	75.7	74°	29.462	79°	61°	73°	68°	.12	N	Fair
	31	29.735	75.71	66°	29.667	94°	54	65	63		SW	Fair
Sept	1	30.065	76.31	65°	29.952	70	54°	67°	64°		S	Fair
	2	30.091	76.31	70°	29.929	85	61	81	67°		N.W.	Fair
	3	29.989	76.18	74°	29.860	87	67	79	70		S.W.	Fair
	4	29.987	76.18	75°	29.860	85°	61	77	73		S	Fair. Overcast
	5	29.809	75.98	76°	29.737	85°	65°	72°	74°			Fair. Overcast
	6	29.829	75.79	78°	29.691	90	62	82	79		S	Overcast
	7	29.877	75.90	76°	29.785	84	69	78	75	.005	NE	Overcast
	8	29.963	76.09	75°	29.732	84	63	75	72		NE	Overcast
	9	29.933	76.08	70°	29.804	78	63	77	74		SE	Fair
	10	30.045	76.32	70°	29.931	81	65	65	64	.01	N	Overcast
	11	30.017	76.35	66°	29.906	67	59	63	63	.035	NE	Rainy.
	12	29.893	75.71	69°	29.776	77	63	74	73	.35	S.W.	Rainy

1	3290 × 400 ÷ 14 =	93,700	= 950 say	1000	0	3.46 =	16,270
2	2280 × 250 ÷ 14 =	103,500	= 1050		- -		16,270
3	1050 × 185 ÷ 14 =	13,900	= 150	150	1.00		1,575
4	460 × 400 ÷ 14 =	13,150	= 125	150			690
5	460 × 110 ÷ 14 =	36,15	= 40	150			690
6	2890 × 50 ÷ 14 =	103,300	= 110	150			4,650
7	1730 × 1150 ÷ 14 =	142,100					
7a	1500 × 750 ÷ 14 =	80,300	= 880	900	$ 4.30		6,450
7b	1730 × 400 ÷ 14 =	49,400	= 550	500	$ 2.91		5,100
8	1770 × 570 ÷ 14 =	72,100	= 800	800	$ 4.00		7,400
9	1115 × 730 ÷ 14 =	58,150	= 640	650	$ 3.24		3,610
10	3150 × 400 ÷ 14 =	90000	= 1000	1000	$ 4.96		15,570
11	2620 × 175 ÷ 14 =	32,740	= 330	350	$ 2.32		6,080
12	2360 × 500 ÷ 14 =	84,300	= 450	900	$ 4.20		10,150
13	3870 × 170 ÷ 14 =	47,000	= 500	500	$ 2.80		10,840
							104,840

Provisional and Rough Determination of a Conducting 3-wire system for Copenhagen Denmark

Specified basis :— Voltage at lamp not to exceed 110.
Pressure Fall in mains " " " 1·4 volts on one side
" " feeders " " " 1·4 " " "
Density of current in conductors " " 200 amp. per sq. cm.
Current in each lamp represented as 0·55 amp.

This means 3·78 Watt per mc. cp.

We have therefore P.D. at lamp 110 110 = 220
" " service 111·5 111·5 = 223
" " junction 112·9 112·9 = 225·8
" " bus bars 126·9 126·9 = 253·8

The mains marked on the chart amount to 19600 metres 64,300 feet.

Provisionally we may assume 13 feeding points and 9 main feeders as follows. There are 21,000 lights on the canvas.

No. of feeder	Position of Bifurcation	Position of Junction	Length on map.	Length in metres	Length in feet.	Lamps supplied	Current supplied	Feeder required.	Report at last price.
1			36 {14, 14}	720 {280, 280}	2360 {920, 920}	1590	400	950 say 1000 amp.	
2						1925	450	1050	
3			16	320	1050	743	185	150	
4			7	140	460	1609	400	150	
5			7	140	460	450	110	150	
6			44	880	2890	200	50	150	
7			15 {11.5, 12}	300 {230, 240}	980 {750, 790}	4576	7(a) 750, (b) 400	7(a) 900, (b) 550	
8						2276	570	(c) 800	
9			17	340	1115	2935	730	650	
10			~~48~~	~~960~~	~~3150~~	1594	400	1000	
10a			~~59~~	~~1180~~	~~2890~~ 2870	681	170	500	
11									
12			25 {15, 11}	500 {300, 220}	1640 {980, 720}	707	175	350	
						1964	500	900	
						21,025	5250		

On the Resistance of Mr Insulls House Mains.

A test of the cable on the 7th July, made the insulation about 10Ω of each conductor. The line is composed of

3 #6 B.W.G. overhead wire each 8800 feet. @ 2.5×10^{-6} = 0·875Ω each
3 #67 E.S.C. cable - - 1050 - @ 1.7×10^{-6} = 0·185Ω.
14,500 ft. Total res: 1·060Ω.

With 50 lamps lit the current would be 12·5 ∫ and the fall of potential in the line 13·25 volts.

Wheatstone bridge measurement of the lines made each 1·225Ω to the meter from the dynamo room.

Res: of Gahon: wire 5385·3 ÷ 2 = 2692·6 ω @ 22·3°C.
integrally 5391 ÷ 2 = 2695·5 recalled.

Barometer Reading 76·00 temp. 66°F Temp. of air at sealing 19·7°C.

Measurement of distances between grooves in the Brashear plane grating. G. III. 90

With 0·001" lines on glass the micrometer distances were

#1.	1001
2	993
3	1005
4	993
5	1012
6	1003
7	1000
8	1000
9	995
10	990
	9991

Mean 999.1 say 1000

10 distances between grooves = 6·75 micrometer revs.
1 " = 0·675 " "
= 0·675 of 0·0001" = 0·0000675"
= 6.75×10^{-5}"
= 14815 to the inch.

The instrument = 14438 " " by engraving.

Discrepancy 3% +

Entry of Conductivity Coefficient for copper with temperature
Test taken by Kennelly + Felsenden 24th April 1890.

This was done experiment on the effect of cooling the bulb instead of heating it. Gasolene & ether were formed round the bulb while air was pumped through. The experiment was spoiled after a certain temperature was obtained by the inrush of an bubble. These were supposed to have been imprisoned between the mercury and the rubber tube. They never interfered while the pressure acted outwards but were drawn in as the pressure acted inwards. The results ought to be reliable however up to the time of first bubbling.

No of Obs	Time	Temp Room Bath	Obsd. res of a th. $\gamma_{\alpha\theta}$	Obsd. res of tre.	Obsd. res of arc.	Ratio of change	Calibration Reading	Res: of Hg.	Temp. of Hg. column	Coeff. of Expn for Hg.	Corrected res of Hg @ 0°C.	Coeff γ
1	21·16	18·6 19·1	10·580	10·530	20·7140		33.268		19.8			
2	·35		·323	·316	·3145		31·628					
			10·257	10·214	20·4285							
3	·50						29.4444					
4	·54	18·5 19·6					26·948		19·8			
5	22·00						24·104					
6	·12						22·911					
7	·15	18·5 19·1	Unreliable.				20·7442		19·6			

This bubble first escaped between these readings.

No of Obs	$(V-1)(\theta+\theta_0)$	Corrected Thermometer at room temp.	Corrected at temp at Obs.	Temp. °C by air thermo.	Res. at obs. for balance	Res: in Gahon at	Res. of wire Gahon at	Ratio.	Ratio of res: wire	Coeff. first	Res for Cell. when put	Ratio
1					14·03 (4)						13·.	
2					13·25 (3)							
3					12·25 (1)							
4					10·75 (3)							
5					8·80 (3)							
6					8·22 (3)							
7					6·74 (1)							

General Mathematical Theory of lighting large areas of cities by electricity considered from an economical standpoint.

3-wire system.

Let d be the drop in volts abs. emf. units permitted in the main
" δ " " " " " " " feeders (full load)
" R " " rad: " cms: of the circular areas lighted
" b " " breadth " " " each block (centre to centre)
" λ " " number of lamps operated in each block at full load.
" γ " " current required for each lamp in abs units.
" ρ " " resistivity of copper in the conductors . . .
" r " " radius of conductor " cms.
" σ " " specific gravity " " " ~~per cc~~
" w " " weight per cm: of main.
" ϖ " " " " " feeder
" W " " total " of copper in mains
" Ω " " " " " " " feeders.
" Γ " " " current.

Then $\because$ the area of the district is $4R^2$, and the area of one block is b^2 there are $\frac{4R^2}{b^2}$ blocks and $\frac{4R^2}{b^2}\lambda$ lamps.

$$\Gamma = \frac{2R^2}{b^2}\frac{\lambda}{2}\gamma = \frac{A\lambda\gamma}{2b^2}$$

Each block requires $4b$ of main. Total length of main is

$$\mathcal{L} = \frac{4R^2}{b^2}\times 4b = \frac{16\pi R^2}{b}$$

The weight of main is such that $d = \frac{\gamma}{2}\frac{\lambda}{4}\cdot b\frac{\rho}{\pi r^2}$

$$\text{and } w = \sigma\pi r^2$$

$$\therefore d = \frac{\rho\lambda b\sigma}{8w}$$

$$\therefore w = \frac{\rho\lambda b\sigma}{8d}$$

$$W = 4\frac{4R^2\rho\lambda\sigma}{2d} = \frac{2R^2\rho\lambda\sigma}{d} = \frac{A\rho\lambda\sigma}{2d}$$

Each feeder supplies 2 blocks. The ~~weight~~ feeders for the first tier are such that

$$\frac{2\lambda}{2}\cdot\frac{\gamma}{2}\cdot\frac{2b\rho}{\pi r^2} = \delta$$

$$\text{and } \varpi_1 = \sigma\pi r^2$$

$$\therefore \frac{2\lambda\gamma b\rho\sigma}{\varpi_1} = \delta$$

$$\therefore \varpi_1 = \frac{2\lambda\gamma b\rho\sigma}{\delta}$$

the weight of these feeders $= \frac{4b^2\lambda\gamma\rho\sigma}{\delta} = p$ say.

Total Weight of 1st tier $= 4p$.
" " " 2nd " $= 8 \cdot 2 \cdot 2p$
" " " 3rd " $= 12 \cdot 3 \cdot 3p$
" " " nth " $= 4n \cdot n \cdot np$.

Aggregate $= 4n^2p = 4\left(\frac{R}{b}\right)^2 p$

$$= \left\{\frac{R}{b}\left(\frac{R}{b}+1\right)\right\}^2 p$$

$$= \frac{R^4}{b^2}p \text{ approximately.}$$

$$= \frac{4R^4\lambda\gamma\rho\sigma}{b^2\delta}$$

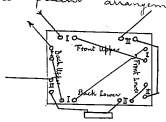
$$= \frac{A^2\lambda\gamma\rho\sigma}{b^2\delta} = \frac{2A\Gamma\rho\sigma}{\delta}$$

$$= A^2\cdot\frac{\lambda}{b^2}\cdot\frac{\Gamma\rho\sigma}{\delta}$$

The total weight of main is thus directly proportional to the area concerned, feeders proportional to the square of the area and the density of illumination.

"Differential Astatic Galvanometer

One of the coils of this instrument having developed a partial disconnection near the bottom end, had to be rewound with 0.002" copper wire. This done the instrument had a resistance of about 13,500ω including a compensating coil and 3ω balanced the two sides for resistance after a fine differential balance for current had been obtained. The present arrangement of circuits is:—



When balanced for resistance a change of 1ω in the res: of either side with 5 volts produces a deflection of 114 divs.
1 " would produce 2.8 " thus 6,750ω
1 ampere " " 18,900 divs. " 18,900ω.

On the most convenient values of the inductance of a pair of parallel cylindrical wires (infinitely long) and remote from magnetic material.

The Maxwell formula is $\underset{(\text{per cm})}{L} = 2\mu\log_e\frac{b^2}{a_1 a_2} + \frac{1}{2}\mu$

$$= 4\log_e N$$

where $\mu = 1$ and N is the ratio of the perpendicular interaxial distance to the common radius of the wire

$$L = \underline{9.212\log_{10} N}$$

If a pair of wires be separated by an interaxial length of 5 diameters, and be each 11 miles long, their inductance will be about 100 metres.

The error introduced into the result by a discrepancy in the measurement is inversely as N.

Formulae for calculating the Inductance of Coils

Perry gives (Electr. Engr 2/6/30 p 211)

n = number of turns
a = mean rad: of winding (cm)
b : axial length
c = axial depth of winding
$b + c < \frac{a}{2}$

Hollow cylindrical coils

$$L \text{ microhenries} = \frac{n^2 a^2 \times 10^{-7}}{1.8444\,a + 3.1\,c + 3.5\,b}$$

$$\frac{L}{R} = \frac{V \times 10^{-3}}{0.728\,a + 1.33\,c + 1.5\,b}$$

For a single circular loop Otto Blathy gives

$$L \text{ (cms)} = 4\pi R \left\{ \log_e \frac{4R - r + \sqrt{16R^2 - 8Rr}}{r} + \frac{16}{15}\frac{R^2}{r^2} - \left(\frac{16}{15}\frac{R^2}{r^2} + \frac{4R}{15r} + \frac{8}{5}\right)\sqrt{1 - \frac{r}{2R}} \right\}$$

or approximately $= 4\pi R \left\{ 0.57944 + \log_e \frac{R}{r} - \frac{2r}{R} - \frac{r^2}{28R^2} - \frac{r^3}{48R^3} - \cdots \right\}$

R = rad: of loop r = rad: of wire in cms.

Tests of a certain asbestos-cement tested for the Sprague Electric Railroad Co.

This cement is made up in 5 lb tins marked as H.W. Johns asbestos retort cement. It sets readily in dry air and rapidly under the influence of heat. The microscope does not indicate the presence of any metallic particles, nor does analysis show any free metal. It is white and pasty. It is supposed to contain potassium or sodium silicate probably the latter.

Two hundred light old pattern meter plates were set at the usual distance in their hard rubber clamps and the spaces between them filled with cement. This was set on the cylinder plate of the engine at a temp. of about 300° F to dry. It hardened superficially round the edges, but after 30 hours a lamp could be lit almost to fill up through the mass, and on forcing the plates apart, the interior was found to be quite soft and pasty.

A test was made of some silicate of soda in the form of a rough right circular cylinder with plane surfaces. Diam. 2.6 length 1.95 gave when tested by bridge a resistance of 1.500 ω say 3.500 ω and 2000 ω with 5 volts 1000/1000 say 5.3 eq. cond. area so that the spec. res. = $\frac{2000}{1.95} \times 5.3 = 5.730$ ω. Using 120 volts and the Siemens tan. galv. a varying deflection of about 45° was obtained from which the resistance would be only 900 ω or 255 ω per c.c.

Tests of the Inductance of a coil and adjustable induction standard the property of Mr Winningham

These were two double coils, the outer one fixed vertically and the inner revolving on a vertical axis passing symmetrically through the outer. About 40 turns of silk covered copper wire are supposed to be wound on each coil. A special meter bridge was employed to test measure the inductance in the belief that it would be too small to measure by secohmmeter but it was found necessary to employ the secohmmeter finally.

No of Obs	Rod. measured	Degree indicator by pointer	Resc.	Bridge	Condenser f	Inductance Hitmeter	Inductance coil	Inductance of standard
1	Standard	0°	3.422	1000/100	0.015	5.133		
2		45°	3.424	-	0.022	7.532		
3		90°	-	.	0.030	10.272		
4		180°	-	-	0.045	15.410		
5	Standard + coil	0°	4.789	-	0.023	11.024	5.893	5.833
6		90°	4.785	-	0.034	16.279	6.0	
7		180°	4.782	-	0.045	21.520	6.11	
8	Coil	—	1.425	-	0.0405	5.771	5.771	
9								

By direct test found the coil to be almost exactly equal to the standard at minimum (0.80°) and the standard min. = −80° of our standard.

Inductance measurements.

Five turns of S.S.C. wire diam. were wound fairly close to one another round a drum of 435·25 cms. circumference. The inductance of these 5 turns compared with the standard coil at minimum position was $\frac{20.4}{79.6}$ .. The same 5 turns were then compared with the inductance of two wires laid on the floor, hard copper 0·041" (0·1041) diam and 17·5 cms apart 12,00 in length. The inductance of this loop would be

$$\frac{17.5}{0.0521} = 336.5 \quad \log = 2.526999 \quad \text{say } 2.53$$

$$9.212 \times 2.53 = 23.3 + 0.5 = 23.8$$

$$12,00 \times 23.8 = 28,560 \text{ cms.}$$

The ratio of this inductance to the 5 turns on the drum was

$$\frac{17.9}{82.1}$$

So that the standard coil at minimum 90° has :-

$$2.856 \times 10^{7} \times \frac{82.1}{17.9} \times \frac{79.6}{20.4}$$

$$2.856 \times 10^{7} \times 4.587 \times 3.903$$

$$2.856 \times 10^{7} \times 17.9$$

$$5.112 \times 10^{5} = 5.112 \text{ kilometres.}$$

The two specially prepared flat leads about 300 long leading to the parallel wires must have had some inductance, say ~~2~~ ×300 = 2800 = 30,500 cms, in which case the standard minimum = 5·46 kilometres.

The inductance of one standard mutual induction coils was measured directly by secohmeter as follows:-

No. of Coil.	Temp B.	Ratio	Res.	Condenser	Inductance Kilometre	Indicated on coil
1	25·3°	10,000/100	2·032	0·0254	5·08	−90°
2		"	2·038	0·048	9·78	0°
3		"	2·038	0·075	15·29	+90°

Comparison of two Standard Legal Ohm coils, one the original Elliott's Standard Legal Ohm no 202, the other the new Elliott Standard checked at Cambridge, no 229 just received here.

22nd July 1890.

Differential Galvanometer Balanced. Res: 13.570 – both coils T.B. 23°C 100%/100. 5w added to one side for res. balance.

Two standards were connected in series, and copper wire wound round their electrodes were led off to the galvanometer. No deflection was obtained the coils balancing. The temp. of no 202 was 23.4°C that of No. 229 22.75°C by #1 thermometer. The balance was repeated later in the evening and found perfect when the temp. of each was 23.75°C.

On the Resistance per mile of 5280 feet that Silicon Bronze Trolley wire should offer in order to meet a specified conductivity.

The resistivity of hard drawn pure copper at zero = 1620 L. units
" @ 75°F = 24°C this would be 1771 " "

a diameter of 0.238" = 0.0141488 sq in = 0.2870" cms.

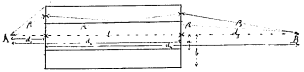
the res: per cm: of pure wire of this diam = 617.97 units
" " " mile of 160,933 cms " " " " = $1.609 \times 6.17 \times 10^{5}$
= 9.923×10^{5} L. units
= 0.09931 Legal ohms

From this we have the following table.

% Cond.	Ohms per mile	% Cond.	Ohms per 1760 yd mile	% Cond.	Ohms per mile	% Cond.	Ohms per mile	% Cond.	Ohms per mile
100	0.993	70	1.419	60	1.655	50	1.986	40	2.483
90	1.103	69	1.439	59	1.683	49	2.027	39	2.545
80	1.241	68	1.460	58	1.712	48	2.068	38	2.612
70	1.419	67	1.483	57	1.741	47	2.113	37	2.683
60	1.655	66	1.504	56	1.773	46	2.159	36	2.758
50	1.986	65	1.527	55	1.806	45	2.207	35	2.838
40	2.483	64	1.552	54	1.839	44	2.257	34	2.920
30	3.310	63	1.576	53	1.874	43	2.310	33	3.009
		62	1.602	52	1.909	42	2.364	32	3.103
		61	1.628	51	1.948	41	2.422	31	3.203.

On the Difference of Magnetic Potential at definite points on the axis of a solenoidal coil, due to the circulation of a given current strength.

Let A & B be the selected points



Let a be the internal radius of the coil
b - - external " " " "
l - its length
c - - mean radius $\frac{a+b}{2}$
ρ - the distances of c from A $= (d_1^2 + c^2)^{\frac{1}{2}}$
ρ_2 - - - - - - " " $= (d_2^2 + c^2)^{\frac{1}{2}}$
β - - - - - - - B $= (d_3^2 + c^2)^{\frac{1}{2}}$
β_2 - - " " " " " $= (d_4^2 + c^2)^{\frac{1}{2}}$
ΔV - - difference of potential between A & B
γ - - current in the coil
N - - total number of turns
n - - number of turns per cm. $= N/l$

Then $$\Delta V = 4\pi n\gamma\left[l - \tfrac{1}{2}\{(\rho_1 - d_1) - (\rho_2 - d_2) + (\beta_1 - d_3) - (\beta_2 - d_4)\}\right] \quad (1)$$

Let $\rho_1 = \beta_1$

Then $$\Delta V = 4\pi n\gamma\left[l - \tfrac{1}{2}\{(\rho_1 - d_1) - (\rho_2 - d_2)\}\right]$$

$$= 4\pi n\gamma\left[l - (\rho_1 - \rho_2) - l\right]$$

$$= 4\pi n\gamma\left[\rho_2 - \rho_1\right] \quad \text{or} \quad 4\pi N\gamma\left(\frac{\rho_2 - \rho_1}{l}\right) \quad (2)$$

If $d_1 = 0$

Then $$\Delta V = 4\pi n\gamma\left\{\sqrt{l^2 + c^2} - c\right\} \quad (3)$$

Let l be very great compared with c

Then $$\Delta V = 4\pi n\gamma l$$

$$= 4\pi N\gamma. \quad (4)$$

On the amount of Rotation produced in the plane of a circularly polarised beam of D light by a plain coil of copper wire wound on a tube of CS_2.

Let e be the current in the wire in abs. electromagnetic units
ε - - e.m.f. on the coil " " " "
r - - res: of - - - - - -
k - - coiling space - - - - - - c.c.
l - - length of - - - - - - cms.
a - - inner rad: - - - - - -
b - - outer - - - - - - -
n - - number of turns
v - - difference of magnetic potential between ends of coil.
θ - - rotation in degrees
φ - - constant of rotation in degrees.
s - - sectional area of coiling space at at angles to axis
d - - diameter of wire
t - - thickness of insulating coat.

Then $$\theta = v\varphi = 4\pi e\varphi n \text{ to a first approximation} \quad (5)$$

$$= \frac{4\pi\varepsilon n\varphi}{r} \quad (6)$$

$$n = \frac{l(b-a)}{(d+2t)^2} \quad (7)$$

$$r = \frac{4\pi k}{\pi d^2 (d+2t)^2} \quad \text{see book II p. 21.} \quad (8)$$

$$\theta = \frac{4\pi^2 e\varphi l (b-a) d^2}{4\rho k} \quad \text{but } k = \pi(b^2-a^2)l \quad (9)$$

$$= \frac{\pi^2\varepsilon\varphi d^2}{(b+a)\rho} \quad \text{where } \varphi = 6.67\times10^{-6},\ \rho = 1.7\times10^{3} \quad (10)$$

If $\varepsilon = 10^8$ $$\theta = \frac{1.2\pi\theta\times10^2 d^2}{(b+a)} \quad (11)$$

This gives the maximum rotation in terms of d, b, and a.

If h be the heat permissable in ergs per sec: per sq cm: of surface

Then see Book II p 136 $$h = \frac{e^2 D^2 d^2}{8\pi b l^2 \rho (b^2-a^2)} \quad (12)$$

Substituting this value of d in the above we have

$$\theta \doteq (d+2t) = \pi l\sqrt{\frac{8\varphi b h (b-a)}{\varepsilon}} \quad (13)$$

and $$\theta = \cancel{\pi l}\,\chi\left(\frac{\pi\varepsilon\varphi}{(b+a)\rho}\right)\left(-t \pm \sqrt{t^2 + \frac{\sqrt{\chi}}{\varepsilon}}\right)^2 \quad (14)$$

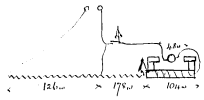
where $$\chi = 8\pi b l^2 \rho h (b^2 - a^2) \quad (15)$$

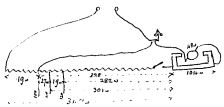
and this gives the rotation possible for a given e.m.f. in terms of the known constants and the dimensions of the coil, to a first approximation.

If λ be the correction for the magnetic length of the coil as obtained from (2), (10) becomes

$$\theta = \frac{\pi\varepsilon\varphi d^2 (l-\lambda)}{(b+a)\rho l} \quad (16)$$

where $$d = -t \pm \sqrt{t^2 \pm \tfrac{l}{\varepsilon}\sqrt{8h\pi b\rho(b^2-a^2)}} \quad (17)$$





Tests of new model series-wound electric light phonograph motor 1st August 1820.

Resistances fixed in the circuit 0·010" gauge	126ω	
- under control of governor - -		178ω
- of field magnets	104ω	
- - armature	48ω	
Res: of machine stopped	278	
- - - when governor lifts		456ω

When cylinder held, and 120 volts on mt. the observed current = 0·089 ebach 0·457 amp. or 29·26 Stdt. ϱ. = 0·428 amp

$\frac{120}{456}$ = 0·263 amp + $\frac{120}{278}$ = 0·432 amp.

When chipping rapidly the current was about 0·42 amp.
- - at 100 revs per min - - - - 0·44 -
- - running light - - - 0·321 to 0·33 amp.

Machine well under control, and generally self starting.

After running on 120 volt pressure for 6 hours, the temp. of the air was 32°C that in the top of the res: was 37·°C, and in the phonograph base 37·5°C.

At 200 revs per min, the current observed was: 0·344

$\frac{120 - x}{278}$ = 0·344 x = 24·4 or 0·122 volts for each revolution per minute

Tests of amended pattern 25th August 1820

The brushes of this machine being altered to the lever type necessitated a readjustment of resistances. as follows

	120 volt	110 volt	100 volt
Field	104ω	104ω	104ω
Armature	48ω	48ω	48ω
Res. permanently in cct.	68ω	46ω	19ω
- under control of governor	282ω	301ω	328ω
	499ω	499ω	499ω

When running at ordinary speed, whether chipping, recording or reproducing the average current is (23·5 Stdt) 0·32 amp. and when held from running (33·Stdt) 0·49 amp.

After remaining in cct. for one hour unrested the temp. rose to 31°C.

For a still later amendment see entry for 3rd Sept page 111

1st–2nd August.

Test of Carrying Capacity of New Standard Edison Meters from Bergmann & Co.

The meters tested were :–

2 # 8 s	one 3-wire	one 2-wire
2 # 4 s	" " "	" " "
2 # 2 s	" " "	" " "
2 # 1 s	" " "	" " "

These were all joined up to lamp banks of 650 lamps in all, each meter taking its full load.

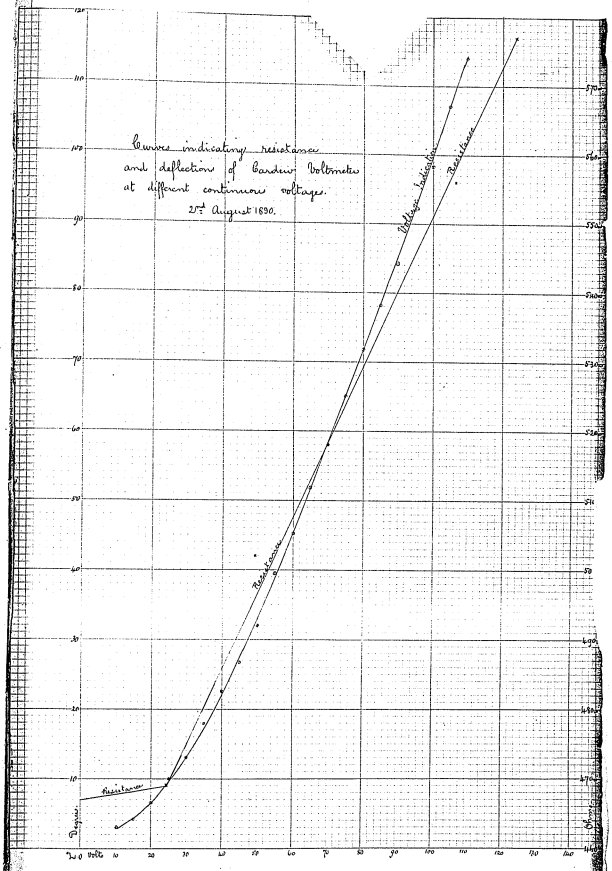
After running for 3 hours the temperatures at the top inside the meter were :– air 33° C.

Meter	# 1 2-wire	# 1 3-wire	# 2 2-wire	# 2 3-wire	# 4 2-wire	# 4 3-wire	# 8 2-wire	# 8 3-wire
Temp. observed	46.4	46.8	45.1	53.5	56	64.4	60.5	63
Rise above air.	8.4	13.8	12.1	20.5	23	31.4	27.5	30.

The last five temperature elevations being considered excessive, long slots pointing 45° downwards were cut horizontally in the backs of the meters, as near the top as possible one slot to each meter, so that the ventilating arrangements now consist of :– a row of 45° pointed holes near the bottom of each shunt, and a ½" slot near the top. The test was then continued until 24 hours had expired with following final temperatures :–

	Meter	# 1 2-wire	# 1 3-wire	# 2 2-wire	# 2 3-wire	# 4 2-wire	# 4 3-wire	# 8 2-wire	# 8 3-wire
Temp. at top	Temp.	38	43.2	43	46.8	49	53	53.8	54.5
	Elevation	8	13.2	13	16.8	19	23	23.8	24.5
	Temp. air 33.0								
Temp. at base	Temp.	30	30.4	32	34.6	34.6	34.2	34.8	34
	Elevation	0	0.4	2	4.6	4.6	4.2	4.8	4

Internal temps.


Curves indicating resistance
and deflection of Bardwell Voltmeter
at different continuous voltages.
25th August 1890.
Voltmeter Deflection
Resistance
Resistance
Resistance
Volts
Ohms

Calibration of Cardew Voltmeter for high potentials.

The resistance of the voltmeter by bridge = 467 ω @ 30°C.

When on 118. volts, the current = 0·0241 Obach = 0·2114 = 552 ω

" - 100·2 - - - = 0·036 - = 0·1875 = 534 ω

- - 124 - - - = 15°55' Std = 0·2165 = 577 ω

- - 106·5 - - - = 14°15' = 0·1965 = 556 ω

- - 49·2 - - - = 7°25' = 0·0981 = 502 ω

- - 24·2 - - - = 3°55' = 0·0516 = 469 ω.

The resistance of the instrument therefore varies with the indication. The resistance used in circuit with the machine consisted of german silver wire wound to 30 ohms doubly on 13 frames of wood, the whole being soaked in molten paraffine wax. This resistance possesses negligible inductance, and has four coils as follow.

	No. 1	500 ω
@ 29°C.	" 2	1032 ω
	" 3	1996 ω
	" 4	4750 ω

Tested up to 1200 volts.

The Cardew was calibrated by comparison with a Weston Voltmeter almost correct in its indications:-

Volts	°Ind.	Volts per $\frac{\Delta v}{\Delta D}$	Volts	°Ind.	Volts per $\frac{\Delta v}{\Delta D}$	Volts	°Ind.	Volts per $\frac{\Delta v}{\Delta D}$	Volts	°Ind	$\frac{\Delta v}{\Delta D}$
10	3	8·3	45	26·8	1·05	80	71·8	0·80	115	122	2·
15	4·2	4·1	50	32	0·66	85	78·1	0·82	117	122·8	
20	6·5	2·2	55	39·5	0·87	90	84·2	0·64			
25	10	1·4	60	45·2	0·76	95	92	0·8			
30	13	1·7	65	51·9	0·7	100	98·3	0·57			
35	17·9	1·0	70	58	0·7	105	107	0·7			
40	22·5	1·1	75	65	0·73	110	114	0·63			
		1·1									

On the effect produced by the insertion of an inductance l in a previously inductionless simple sine alternating circuit of emf E frequency p and resistance r.

The current previous to insertion will be $c = E\sin pt/r$

after insertion it will be $c = \frac{E}{r}\sin pt - \frac{l}{r}\frac{dc}{dt}$ $\qquad p = 2\pi n$

$$\text{or} \quad T\frac{dc}{dt} + c = \frac{E}{r}\sin pt$$

$$\frac{dc}{dt} + \frac{c}{T} = \frac{E}{l}\sin pt$$

$$\therefore \quad c = \varepsilon^{-\int\frac{dt}{T}}\left(\int\left(\varepsilon^{\int\frac{dt}{T}}\frac{E}{l}\sin pt\right)dt + \kappa\right)$$

$$= \varepsilon^{-\frac{t}{T}}\frac{E}{l}\int\left(\varepsilon^{\frac{t}{T}}\sin pt\right)dt$$

$$= \varepsilon^{-\frac{t}{T}}\frac{E}{l}\left\{\frac{\varepsilon^{\frac{t}{T}}\left(\frac{\sin pt}{T} - p\cos pt\right)T^2}{p^2T^2+1}\right\}$$

$$= \frac{E}{l}\left\{\frac{\sqrt{\frac{1}{T^2}+p^2}\left\{\sin(pt-\theta)\right\}T^2}{T^2\left(p^2+\frac{1}{T^2}\right)}\right\}$$

$$= \frac{E}{l}\,\frac{\sin(pt-\theta)}{\sqrt{\frac{1}{T^2}+p^2}}$$

$$= \frac{E}{r}\,\frac{\sin(pt-\theta)r}{\sqrt{r^2+p^2l^2}}$$

$$= \frac{E}{\sqrt{r^2+p^2l^2}}\sin(pt-\theta)$$

where $\theta = \tan^{-1} pT$ or $\tan^{-1}\frac{pl}{r}$

Problem:– A resistance r having an inductance l is connected in series with a condenser of capacity k and a periodic emf a simple harmonic function of the time, determine the permittance of the condenser which shall annul the self induction

Let v be the instantaneous p.d. on the pair so that on the condenser

Then $v - u = l\frac{dc}{dt} + cr$

$$v = E\sin pt$$

$$u = e\sin(pt-\theta)$$

$$c = k\frac{dv}{dt} = pEk\cos(pt-\theta)$$

$$\therefore \quad E\sin pt = E\sin(pt-\theta) + pekr\cos(pt-\theta) - lkep^2\sin(pt-\theta)$$

$$= E\left\{\sin(pt-\theta)(1-lkp^2) + pkr\cos(pt-\theta)\right\}$$

$$= E\sqrt{(1-lkp^2)^2 + p^2k^2r^2}\cdot\sin(pt-\theta+\phi)$$

When $l=0$ and $k=\infty$ $c_{max} = \frac{E}{r}$

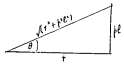
under present conditions $c_{max} = k\frac{dv}{dt} = kEp\frac{E}{\sqrt{(1-lkp^2)^2+p^2k^2r^2}}$

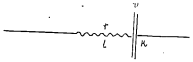
$$\therefore \quad p^2k^2r^2 = (1-lkp^2)^2 + p^2k^2r^2$$

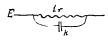
$$\text{and} \quad p = \frac{1}{\sqrt{lk}}$$

$$\text{or} \quad \sqrt{k} = \frac{1}{p\sqrt{l}}$$

$$k = \frac{1}{p^2l}$$







Let $e = E\sin pt$

$$q = \frac{E\sin(pt-\tan^{-1}pT)}{p\sqrt{(1-p^2T^2)}}$$

$$c_k = k\frac{de}{dt} = kpE\cos pt.$$

$$c_l + c_k = \frac{E\sin pt}{r}$$

$$\therefore \quad \frac{E}{r}\sin pt = \frac{E}{r}\frac{\sin(pt-\tan^{-1}pT)}{\sqrt{1-p^2T^2}} + kpE\cos pt.$$

$$\frac{\sin pt}{r} = \frac{\sin(pt-\tan^{-1}pT)}{r\sqrt{1-p^2T^2}} + kp\cos pt.$$

$$k = \left(\frac{\sin pt}{r} - \frac{\sin(pt-\tan^{-1}pT)}{r\sqrt{1-p^2T^2}}\right) \div p\cos pt$$

$$= \frac{1}{pr}\left\{\tan pt - \frac{\sin pt - \tan^{-1}pT}{\cos pt(\sqrt{1-p^2T^2})}\right\}$$

Amplitude of Main Current
Line of Short Circuit
Line of Open Circuit
Reactances per phase.
Volts Amp.

Test of Small Meter Motor whose design is recorded on pages 74-75. August 4th 1890.

The instrument has a vertical steel shaft and runs on centers. There are 18 segments on the commutator ring. Armature each wound in two layers of 21 turns = 756 which in all of drawn 0.
The resistance of the armature and its connections = 0.34 ω.
Fields are wound with silk covered copper wire diam.
The resistance of the left hand field = 3980 ω
" " " right " " = 3290 ω.
The instrument was connected up to a sample #1 Meter 3-wire with its two strips in series through a piece of copper wire. A little more than double the standard pressure is therefore supplied to the motor. The following observations were taken with the dial recording.

No. of Obs.	Lamps in ckt.	Pressure on mains Volts	Ohmeter Reading in Main ckt.	Amperes in Lamp ckt.	P.D. at Motor terminals.	Revs. per min. of motor		e.m.f. generated by motor	Resistance in motor ckt.	Energy consumed by motor.
1	1	109.5	0.11	0.564	0.062	11.75				
2	2	109.5	0.195	1.00	0.128	45				
3	3	109.5	0.297	1.523	0.200	75	30			
4	4	107	0.395	2.026	0.270	113	38			
5	6	107	0.602	3.088	0.420	174	61			
6	8	107	0.787	4.037	0.554	235	61			
7	10	106.8	1.000	5.128	0.712	300	65			
8	12	106.8	1.175	6.026	0.834	349	49			
9	14	107.5	1.370	7.026	0.980	400	51			
10	16	107.5	1.550	7.950	1.110	447	47			
11	18	107.5	1.710	8.770	1.224	482	35			
12	20	108	1.920	9.846	1.374	534	52			
13	20		1.92	9.846		618	One field coil			
14	20		1.92	9.846		616	Both	in series		
15	20	107.5	1.92 Shunts in series	9.846		536	Both	multiple		
16	20	107.5	0.285 Armature series	1.462	1.270	510	0.783		1.462	0.255 1.145 generated 1.4 Pot. absorbed
17	20	106	0.285	1.462	1.276	680	0.783		1.462	
18	1	108.5	0.03 Armature series to field position	0.154	0.06	8.75			0.154	0.0092 Watt absorbed
19	1	108	0.03	0.154	0.06	8.25			0.154	

The motor generates 0.00153 volt for each revs. made per minute
" " and 0.0918 volt " " " " " second.

The starting current is seen to be 0.4 amp. producing a p.d. at armature terminals of 0.0512 volt: This would cause a current of

$$\frac{0.0512}{0.31} = 0.165 \text{ ?} \therefore c = 0.0165, \quad w = 756$$

$$\varphi c w = 10^8 \times 1.53 \times 10^{-3} \times 60 = 1.53 \times 10^5 \times 60$$

$$\varphi = 60 \times 1530 \times 10^3 / 756 = 12{,}140$$

$$\frac{\varphi c w}{2\pi} = \frac{1.2140 \times 10^4 \times 1.65 \times 10^{-2} \times 0.756 \times 10^3}{0.62932 \times 10^1} = 2.410 \times 10^4 \text{ dyne cm.}$$

The starting torque for this motor was thus about 25 gm. cms.

Test of Motor-Meter when running in reverse direction. Fans curved back. 19th Aug. 30.

Connections same as in last test

No. of Trial	Number of lamps	Block	Current in Main cct. amperes	P.D. on Shunt	Approx. no. of Shunt	Speed of motor revs per min	P.D. on mains		
1	1	0·100	0·505	0·05		5	128 v.		
2	2	0·210	1·061	0·126		43			
3	4	0·462	2·333	0·396		127			
4	6	0·700	3·536	0·460		211			
5	8	0·905	4·572	0·600		288			
6	10	1·155	5·833	0·774		382			
7	12	1·360	6·870	0·910	1·325	462			
8	14	1·550	7·830	1·0444	0·133	530			
9	16	1·760	9·02	1·200		615			
10	18	1·960	10·06	1·298		655			
11	20	2·100	10·77	1·398	0·13 "	765			

The removal of the glass cover from the instrument when running at full speed was found to reduce the speed about 70 revs per min, and this effect was repeated on several occasions.

Six tubes of prepared paper intended for underground conductors were received from the Interior Conduit Co. on the 21st Aug. They were all left submerged in the tank on roof same day to soak, in order to give their insulating properties a thorough test.

On the test iron wire winding for the field magnets of the motor meter. The resistances of the core has to be say 5000 ohms each and the coiling space 180 c.c. on each magnet. $\rho = 12000 = 1.2 \times 10^{4}$

$$\frac{180}{5000} = \frac{18.0 \times 10^{1}}{5.0 \times 10^{3}} = 3.6 \times 10^{-3}$$

$$d = -t \pm \sqrt{t^2 + 3.568 \times 10^{-5} \times 1.1 \times 10^{2} \times 1.19}$$

$$\pm \sqrt{7.457 \times 10^{-3} + t^2}$$

0.00746

74.6×10^{-4}

8.64×10^{-2}

0.06644 cm.

$= 0.0344" - 0.002$

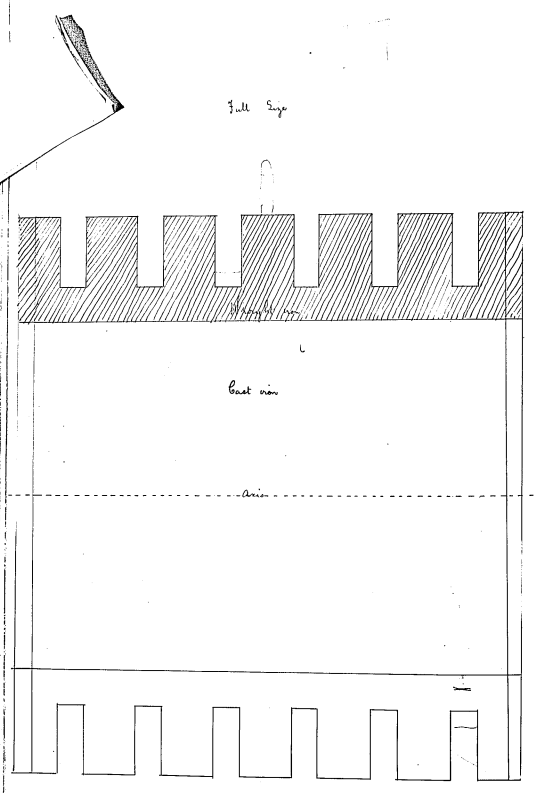
$= 0.032"$

$$= -t + 0.06654 \sqrt[6]{\frac{180}{5000}} = 0.06654 \sqrt[6]{3.6 \times 10^{-2}}$$

$$+ 0.06654 \sqrt{1.899 \times 10^{-1}} = 0.06654 \times \sqrt{18.99 \times 10^{-2}} =$$

$$+ 0.06654 \times 4.358 \times 10^{-1} \quad 0.02885 = 0.0330" - 0.002 = 0.0310"$$

$= 3.1$ mc.



On the dimensions necessary for a magnetic pulley to drive a car axle from an armature shaft.

Let the attraction due to magnetism between pulley & bar be 70 lbs per sq. in. of cross section, and the peripheral velocity of the armature pulley = v = feet per second.

n = be the ratio of the first gear
d = " " diameter of the armature pulley
D = nd " " " " intermediate "
h = one side of the bar.
θ = angle of embrace in this case assumed at 180°
P = pull in lbs. weight transmitted
p = pressure of each bar on the pulley.

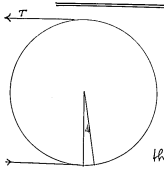
Then $\frac{\pi d}{2a} \times \frac{2}{3}$ = the number of bars in contact
$70a^2$ = p = pressure on each bar in lbs. wt.
$14a^2$ = f the plane surface resistance to slipping in lbs. wt.
$14ad$ = F " " " " " " of all the bars.
$40P$ = 40×550 = 22,000 ft lbs. per sec.
v = πd = 30
F = 730 lbs weight
$14ad$ = 730
ad = 52

With a pulley having an 8" face and provided with 6 grooves with an external diameter of 8", and bars ⅜" square, the face of the drum should be $2 \times \frac{3}{16}$" = $\frac{3}{8}$" with ⅜" for winding = 3/16" say 1¼". 6 × 1¼ = 7½" − ⅜" = 6⅞".
If the grooves have a depth of 1", the winding space will be ⅜" × 1". The cross section of the bars is 0.91 sq. cms, and at 14,000 lbs per sq. cm, the normal pull = $\frac{p}{sg}$ = grammes per sq. cm.

$$\frac{0.98 \times 1.96 \times 10^6}{25 \times 1000} = \frac{1.8 \times 10^6}{2.5 \times 10^4} \text{ grammes} = 7.2 \times 10^3 = 7.2 \text{ kgm}$$

= 45.2 kgms for each bar = 9 kgms traction per bar on a plane surface. With 2 bars to the inch, the pull is $2 \times \frac{8}{3} \times \frac{\pi}{2} \times 9$ = 225 kgms pull on a plane surface.

Mathematical theory of magnetic belt transmission.



Let t be the tension on the belt at any point
θ - - angle of embrace
r - - rad: of pulley
m - - magnetic pressure per radian (dyne)
p - - total pressure at any point . . .
μ - - coefficient of friction.

Then at any small increment of angle $d\theta$ the tangential forces satisfy the relation

$$(t + dt)\cos d\theta = t + \mu p\, d\theta$$

and the normal forces

$$p\, d\theta = 2t \sin \frac{d\theta}{2} + m\, d\theta$$

$$\text{or } p = t + m$$

$$\text{and } dt = \mu (t + m)\, d\theta$$

so that

$$\frac{dt}{t+m} = \mu\, d\theta$$

and

$$\int_T^t \frac{dt}{t+m} = \mu \int_0^\theta d\theta$$

$$\log_e \frac{t+m}{T+m} = \mu\theta$$

$$\text{or } t + m = \varepsilon^{\mu\theta}(T + m)$$

$$t = T\varepsilon^{\mu\theta} + m(\varepsilon^{\mu\theta} - 1)$$

In a belt whose weight would be negligible

$$T = m(\varepsilon^{\mu\theta} - 1)$$

Next consider a discontinuous belt of n bars angle ϕ

$$T_1 = T\varepsilon^{\mu\phi} + m(\varepsilon^{\mu\phi} - 1)$$

$$T_2 = T_1\varepsilon^{\mu\phi} + m(\varepsilon^{\mu\phi} - 1)$$

$$T_3 = T_2\varepsilon^{\mu\phi} + m(\varepsilon^{\mu\phi} - 1)$$

$$T_n = T_{n-1}\varepsilon^{\mu\phi} + m(\varepsilon^{\mu\phi} - 1)$$

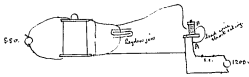
$$T_n = T\varepsilon^{n\mu\phi} + m(\varepsilon^{n\mu\phi} - 1) \quad \text{approximately.}$$

In practice the arc of embrace is at least π and $\mu = 0.2$ which $n\phi$ = at least 2

$$\therefore \quad T_n = T\varepsilon^{0.4\pi} + m \times 0.5$$

so that neglecting weight $m = 2T_n$

or the magnetic pressure per radian must be double the pull to be transmitted.



Test of seven Wirt lightning-protectors received from Harrison N.J. 21st August. 1890.

An induction coil, whose secondary is fully described on page 58 was excited by the Z machine at about 5·5 volts p.d. The terminals of the secondary were led to a battery of 6 Leyden jars of some 14 cms. int: diam., and 18 cms inside mean depth. The thickness of the glass being estimated at 0·2. This gives an area of 154 sq. cms. for the base and 792 sq. cms. on the sides = 946 sq. cms. in all for one jar = 5700 sq. cms. for the battery and a capacity of $\frac{5700}{1257} \times 1{\cdot}7$ = 4310 abs. e.s.u. $= \frac{4310 \times 10}{9 \times 10^{10}} = 480 \times 10^{-5} = 0{\cdot}0048$ microfarads.

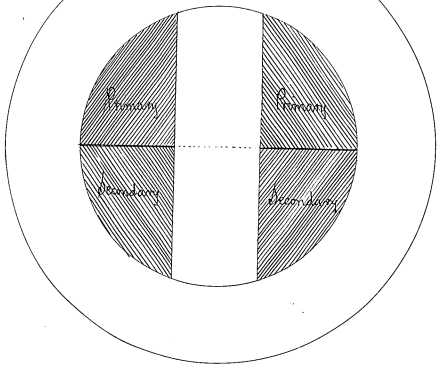
The spark produced by their discharge between two very slightly convex surfaces was 0·8 cms long equivalent to 26,400 volts. the discharging quantity $26{,}400 \times 0{\cdot}0048 = 2{\cdot}64 \times 10^{4} \times 4{\cdot}8 \times 10^{-3} = 12{\cdot}65 \times 10^{-1} = 126{\cdot}8$ microcoulombs (Check 88 abs. e.s. emf. × 4310 = 379,400 abs. qu. e.s. $= \frac{3{\cdot}794 \times 10^{5}}{3{\cdot}0 \times 10^{10}} = 1{\cdot}265 \times 10^{-5}$ = abs. e.m.u. $= 1{\cdot}265 \times 10^{-4}$ coulomb = 126·5 microcoulomb.)

This discharge was produced over the surfaces of the protectors, and the particulars of these are shewn below. The municipal dynamo generating about 1200 volts was connected direct with the terminal of the lightning protector through a safety catch, and plate after plate cut out, until the dynamo ceased followed the Leyden jar discharge.

No. of Test.	Number of Protector	Diameter of Number.	Length mm plates	Number of Plates	Material of Plates	Number of washers mm which differed	Number of washers mm which mm 2nd not differ	Number of washers mm which dynamo ceased		
1	#25	1 7/8"	5 5/8"	47	Brass	3	4	–		
2	15	"	3 1/8	29	"	3	4	2		
3	15.B	"	"	"	"	3	4	–		
4	6 A	1 7/8"	1 5/8	15	Copper	4	5	–		
5	6 B	1 7/8"	1 5/8	15	Brass	3	4	–		
6	4 A	1 7/8	1 1/4	10	"	3	4	–		
7	4 B	1 7/8	1 1/4	10	–	3	4	–		

Instrument packed with the screws still left on the metal and returned to Harrison N.J. The internal insulation was not perfect although the surface was cleaned with a hot towel, but it was sufficiently good for all requirements. The defect was known because when the discharging point was presented at A it would sometimes not precipitate an arc but would immediately do so when presented to B.

Full size cross section.



Description and Data of the first Edison Transformer completed 22nd August 1820.

This was built to compare with the Westinghouse #2 whose description is given on page 10.

The primary coil is of # 22 B.+S. 0·644, 2 lbs. 12 oz = 1247 gms. 1247
has 15 layers (58, 58, 58, 58, 57, 57, 55, 55, 52, 50, 48, 46, 46, 44, 41, 40) and 768 turns.
and a res: of 22·5 ω approx.

The secondary coil is of # 8 B.+S. 0·128", 3 lbs. 7 oz = 1560 gms. 1560
has 6 layers (8, 7, 6, 6, 5, 3) = 35 turns.

The interior core weighs 8 lbs 10½ oz = 3927
" exterior " " 31 " 13 " = 14430
Frame 726
Total 21890

External diameter over iron 15·65 } 2·78 = thickness of shell.
Int " " " 10·1 } Area 192·3 − 80·1 = 112·2
Length over " 20·4 } Vol: 112·2 × 20·4 = 2289 cc.
" coils 27.

Breadth of interior core 3·15 vol: 668 = 668 ..
Total vol: 2957 ..

Total weight of iron 18360 ~~Spf. Gr.~~ Sp. g. 6·21

Connected this & the West: transformer in parallel with the bipolar alternator making some 1500 revs. per min or 25 ~ per sec. at 1000 volts p.d. the transformer primaries overheated owing to the small frequency, so that it became necessary to reduce the pot to some 300. The Edison transformer became ~~[illegible]~~ the hotter. At 300 volts (270 max) the two secondaries were taken alternately to a noninductive circuit with a dynamometer in it. The mean deflection with the W. transformer the 1st + leads was 80° = 8·3 × 0·9 = 7·47 amp. mean, and with the E. transformer was 65° = 7·48 × 0·9 = 6·73 = 90% of the W. result. The mean e.m.f. in the secondary cct: would only be 10 to 12 volts.

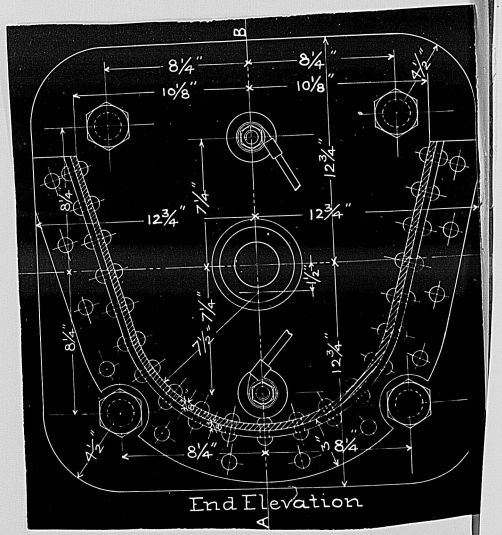
To double the pressure of the supplied secondary current it is necessary to employ twice as many turns. The diam: of the present covered is 0·154" and a wire of half that area = 0·109" = 0·083" copper = # 14 B.W.G. or # 12 B.+S. 70 turns

On the 2nd September another test was obtained using the 1200-volt Siemens alternator. The speed of the machine was not taken but the converter note was identified with 3 flat or 42·5 = 106 ~ per sec.

The secondary terminals of each machine were led to a bank of 53 100-volt lamps in succession, the primaries being permanently in circuit, and the following readings obtained on dynamometer

	App.	amp.	Mean	App.	amp.	Mean	App.	Mean	
West:	75°30'	8·06	7254	71°	7·8	702	76°40'	8·1	729 } after half an hour, the West: min, and the
Edi:	66°15	7·6	6·84	62·15'	7·4	666	64°15'	7·4	666 } Ed: primary) coil were hotter.
			94·3%			94·8%		91·3%	

Mean 93·5%



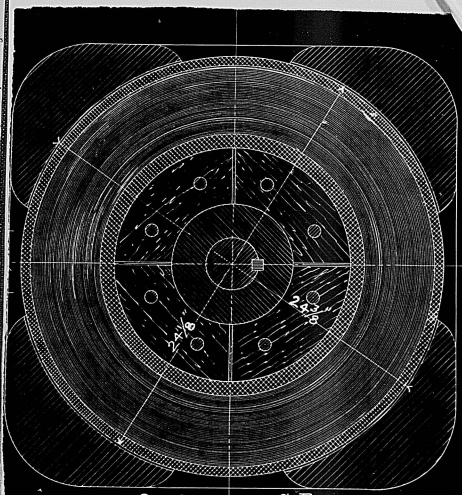
End Elevation

Memoranda

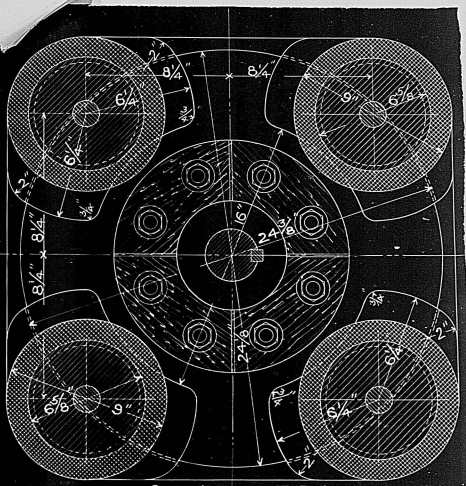
5.50 ~~cubic~~ inches per lbs of winding space
0.18 lbs . cubic inch . . .

Double-cotton covering on armature wire .005" - 0.0075" ...
Single - . .. magnet - 0.008" - 0.012" ..

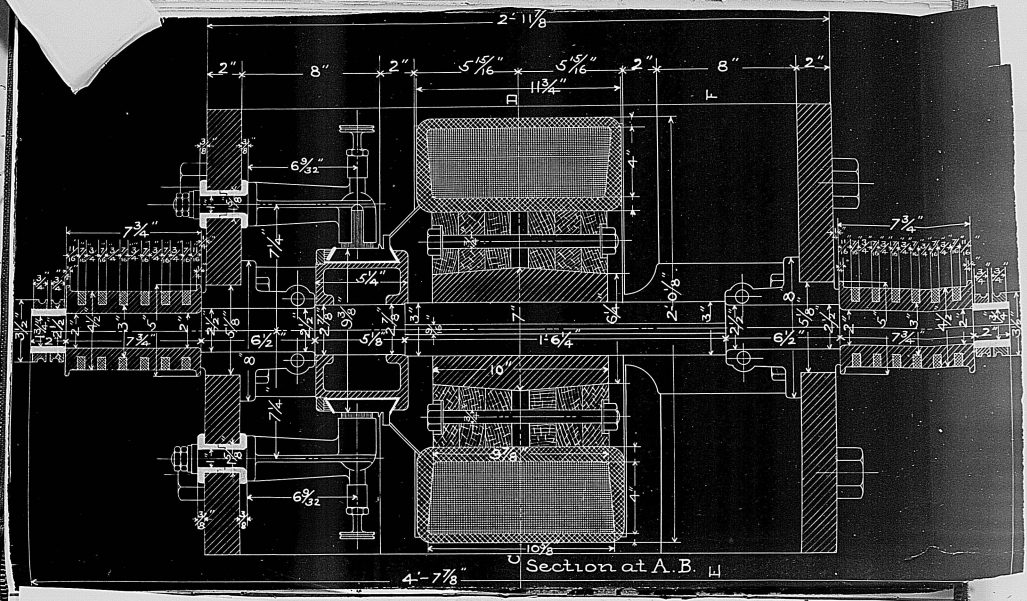
N.B. The brushes in this motor are indicated at 180°. Their true position should be at 90°



Section at C.D.



Section at E.F.


2'-11 1/8"
2"
8"
2"
5 15/16"
5 15/16"
2"
8"
2"
11 3/4"
A
L
6 9/32"
7 3/4"
7 1/4"
5 1/4"
2'-0 1/8"
1'-6 1/4"
6 1/2"
5 1/8"
10"
5 7/8"
10 7/8"
4'-7 7/8"
Section at A.B.

Data of a quadripolar tram motor to drive a 7½ ton car (loaded) 4 miles per hour up a 12 % grade.

Voltage at M.T. 500. Work required to be done at car axle = 22 HP or 30 HP allowing for loss in gearing. = 22.5 kwts and at 90% eff. = 25 kwts = 50 amperes absorbed at full load.

Torque. 1950 lbs. at periphery of wheel = 2,440 lbs. on 24" wheel = 488 lbs. at periphery of armature.

Speed 700 revs. per min. @ 12 miles per hr. = 132 revs. of wheel per min.
233 . . @ 4 . . . = 44 . . . . .
3.89 . . sec @ 4 . . . = 0.73 . . . . .

Diam. of armature 24" over all. circ. = 75.4" = 6.29' = 4400 feet per min at full speed 4 1470 feet per min. @ 4 m. per hr.

Flux: Useful flux 4,180,000 and with r = 1.6
Total flux 6,688,000 through each polar head.

Density in armature 8000 – pressed iron
. . core 15,500 – wrought iron
. . keeper 15,500 – " "

Armature Dimensions

External diameter	23⅛"	= 58.72
Depth	4"	= 10.15
Internal "	15⅛"	= 38.4
Mean breadth	10.1"	= 25.65
External "	10 5/8"	= 28.24
Internal "	9⅞"	= 25.08

Area of cut: circle 2711 } area of annulus 1555
. . int. " 1156 } Cross section 40.5 257
Volume of armature 399,635 c.c.
Sp. g. 4.9 Mass = 1950 kgms = 4400 lbs.

Wire $3.89^{n} \times 3072^{w} \times 4.18^{g} \times 10^{6} = 500 \times 10^{9}$

3072 wire all round
4 layers of 768 (of 192 in a segment)
1/32" between each block of 6.
#16 B.W.G. 0.065" = 0.080" cond = 4,225 cmil.
Armature body insulation 1/32" Clearance 1/8" Entifer 1.68 cm
Mean turn 31"
Total length 7930'
Resistance 19.8 ω in series = 1.24 ω in multiple = 1.33 ω bt. Drop at full load 67 volts.
Weight of wire on armature 110 lbs.
Torque at full load (15 lbs per amp. at periphery) = 750 lbs

Cores Wrought iron 215 sq cms 33.3 sq. in. = 16.55 cm 6⅝" diam.
Length 8" 20.3 cms = 43.650 c.c. × 7.8 = 340.5 kgms
= 75 lbs each or 600 lbs. in all.

Armature weight Iron wire 430 lbs.

copper	110
Commutator	75
Shaft	75
Wood	50
Shell	60
	800

Magnetic circuit.

Air space 1.68

Area of pole face, one side. $2 \times 260 = 520$
on surface 770 f 1290

½ of pole surface = 322

Iron keepers 30 cm. area 108 sq. cm. $\mu = 300$ $\mathcal{R} = 15{,}500$

Cores 21 - each area 108 . . $\mu = 300$. = 15,500

Pole heads exact iron

Air	$\frac{1.7}{322}$	=	0.0056
Cores	$\frac{42}{107.5 \times 300}$	=	0.0011
Keepers	$\frac{30}{107.5 \times 300}$	=	0.0011
Pole heads		=	0.0010
Total		=	0.0088

$1.257\ A.T. = 0.0088 \times 1{,}672{,}000$

$A.T. = 11{,}700$ or 5,850 per spool

Allowing for armature effect = 7000 " .

With 12.50 Watts lost in field = 2.5 amperes = 200 ω in field = 25 ω per spool. Mean turn = 2' = 5600' = 2800' = 224' per spool ω = # 18 B.W.G. 0.044 g" = 0.057" cond. = 1.69 lbs per ω = 42 lbs per spool = 336 lbs. on all.

42 lbs × 5.5 = 232 c.i. 8" = 9" ext. diam.

Belt pulleys—

Two pulleys 4.5" diam: six grooves in each ⅜" × ⅜" deep
10 # 11 B.W.G. wire 0.120" = 0.135" cond. in each groove = 60 turns per pulley = 60 feet

Two pulleys 24" diam: two grooves in each 10 wires in each groove 1" deep = 60 feet in each pulley.

240 feet of wire in all four pulleys = 0.25 ω 625 Watts at 5/8 load
120 - - #11 wire - two clutches = 0.13 ω Total 950

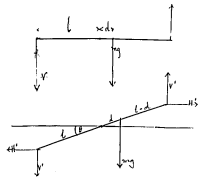
Measurement after building.

Res: of the armature between brushes measured = 1.15 ω cold say 18°C.
" " each core 25 ω 22 layers of 112 turns = 2464 turns in all.
" " all 8 in series 200 ω.
" "

Inductance of field magnets.

From the measurements recorded on page 126, $\varphi = 1.99 \times 10^6$ per core with 2.25 amperes = 8.842×10^5 lines per ampere. There are 2464×10^3 turns per core so that 2.179×10^9 lines are linked with the circuit in each core = 17432 quadrants for all 8 magnetic cores.
The resistance being 200 ω, the normal time constant = 0.087 second.
The electrokinetic momentum with 2.5 amperes is 3.922×10^3 abs. units = 39.22 lbs.
" " energy 4.41×10^8 = 44.1 Joules.
" total quantity discharged on short circuit = 2.25 × 0.087 = 0.196 coulomb.

On the mathematical relations between the dip of the magnetic ore needle and the magnetic components producing that dip



Let H be the horizontal component at locality of balancing
V . . vertical .
H' . . horizontal . . . testing
V' . . vertical . . . . .
$2l$ . . lengths of the needle between mg & d
d . . distance of center of inertia from axis
m . . mass of the needle
θ . . angle of dip
p . . strength of one pole

Then $2lVp - dmg = 0$ (1)

$2lVp\cos\theta - dmg\cos\theta - 2lpH'\sin\theta = 0$ (2)

$2lV'p\cos\theta - 2lVp\cos\theta - 2lpH'\sin\theta = 0$

$V'\frac{p}{p} - V - H'\tan\theta = 0$

$V' = V + H'\tan\theta$ (3)

If then a dipping needle be loaded by a balance weight at a locality where the vertical intensity is known then at some other locality let the true dip (unloaded) ϕ

$H'\tan\phi = V'$

and the dip loaded $= \theta$

Then $V' = \dfrac{V}{1 - \tan\theta\cot\phi}$ (4)

and $H' = \dfrac{V\cot\phi}{1 - \tan\theta\cot\phi}$ (5)

also I' the intensity $I' = \dfrac{V\operatorname{cosec}\phi}{1 - \tan\theta\cot\phi}$ (6)

$1.1 \times 0.333 \times 10^{-15} \times 10^{8} = 0.3663 \times 10^{-7}$ abs. qu.

118 dis $= 3.663 \times 10^{-8}$ " "

1 dis $= 3.105 \times 10^{-10}$ " "

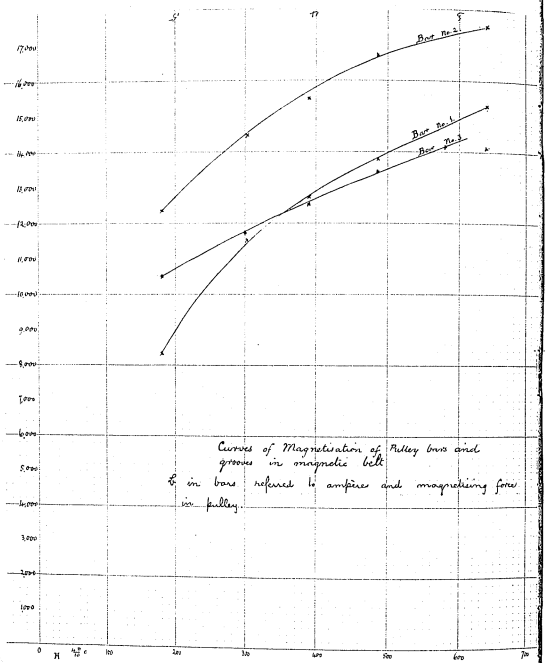
$d \times 3.105 = q^{n}$

$\frac{4}{12} \times 6.5 \times 10^{12} = q.5.418 \times 10^{11} = q$

$\frac{9}{12} \times 17.5 \times 10^{12} = q.1.458 \times 10^{12}$ "

$6.45 \times 0.25 = 1.61$

$H = \frac{2\pi}{10} \times 8 \times$ ampères $= 10 \times$ ampères for each groove.



Curves of Magnetisation of Pulley bars and grooves in magnetic belt

B in bars reduced to ampères and magnetising force in pulley

Measurements of the Magnetic Induction through the bars of the magnetic belt resting on the pulley of the car motor

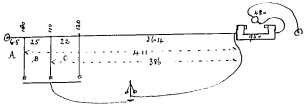
The pulley diameter was 4·5" and its face was 7½" as shewn on the blue-print facing p. 110. The bars were 7" long and ½" × ⅛" so that their cross section was ⅛ sq. in. They were ground to the curvature of the pulley on one face, and were threaded on seven composite steel wire rack-ends of 1000 lbs breaking stress each. The space between consecutive bars was about ⅛". A wire was wrapped round each one bar once to each groove and taken to a galvanometer while a measured current passed through the pulley wire. This was # 11 B.W.G. 0·12" 48 turns in all 8 per groove in 4 layers deep and two wires broad. Three bars were measured. No 1. was found to be slightly bent and to be out of complete contact with the pulley. No 2. was in good contact, and No. 3 was a bar of annealed iron. Pulley and bars were both wrought iron. The following table shews the results which are only approximate as the galvanometer was not ballistic, i.e. &c.

No. of Obs	No. of bars	Current in Pulley amperes	Throw Mean	$\frac{4\pi n}{10}$	q.	φ	B in sq. cm. section of bar	Throw for 5Ω. Nimrod with 0·3337	Values of 1 div. in quantity	Number of linkages.	No. of G.
1	1	64	146·5	2	4·568 × 10	24,640	15,300	118	3·105 × 10⁻¹⁰	6	6,500
2	2	62	168·0	2	5·216	28,260	17,560			× 2 for reversal.	
3	1	48·5	132		4·099	22,210	13,800				
4	2	49	160		4·967	26,910	16,710				
5	1	39	122		3·788	20,520	12,750				
6	2	39	148·5		4·610	24,970	15,510				
7	1	30·3	110·5		3·43	18,580	11,540				
8	2	30	138·5		4·30	23,300	14,470				
9	1	18	80		2·48	13,440	8,350				
10	2	18	118·5		3·679	19,920	12,380				
11	3	18	100·5		3·120	16,900	10,500				
12	3	32	112·5		3·49	18,900	11,740				
13	3	40	120		3·73	20,210	12,550				
14	3	50	129		4·00	21,670	13,460				
15	3	58	135		4·19	22,700	14,100				
			45 (11,000 in int.)		1·397	20,360					

The pulley at 50 ampères sustained on the belt a pull of 275 lb weight without slipping with 9 bars and an angle of 100° (50° of contact)

for 200 ampères T lbs $= 275 \left(\frac{E^{\frac{\mu 100\pi}{180}} - 1}{E^{\frac{\mu 100\pi}{180}} - 1} \right) = 275 \times 2{\cdot}66 = 730$ lbs.

allowing for the assistance of initial weight and tension the pull may perhaps be 900 lbs on each pulley.

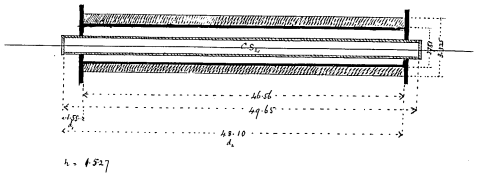


Measurement of Resistances of New Model Phonograph 3rd Sept. 20 (110 volt).

	Set for 100 volts	Set for 110 volts	Set for 120 volts.
Res: permanently in circuit	6·5 ω	31·5 ω	53·5 ω
" of field	9·5	9·5	9·5
" " armature	4·8	4·8	4·8
" " machine governor down	149·5	174·5	196·5
" under control of governor	4·11	3·86	3·64
" of circuit governor up	561·5	561·5	561·5

Two battery machines were tested. They differed only in the boring of the polar face circle. No 1. had the usual clearance. No. 2. was bored about $\frac{1}{32}$" larger on a side and so had about $\frac{1}{32}$nd. inch more clearance. The same body was used on each in turn. The current required to drive No 1. ~~reproducing~~ but not chipping was (79°·30') 2·~~785~~ amp that to drive No 2 at same speed (109 revs of cylinder per min) ·75° 2·814 amp = 9·5% more current.

27th Jany 92, a trial was made at the Phono: Works of a coil of 52 ω q.s. same size as usual for the res A (0.012" wire) and a 16 cp. lamp under control of governor without any play switch or resistances B, C. This arrangement worked satisfactorily and adopted as standard at 120 volts.



Experiments with an Optical Voltmeter

The helix was formed of No 30 B.W.G. 0.012" ·00048 covered with silk to 0.015" ·00581 in 8 layers of approximately 1200 turns each on a brass tube 4.6.56 between flanges and 2.781 in diam. (1.095"). The external diameter over the wire being 1.309" 3.325. The resistance of the helix was about 205ω @ 19°C.

The tube containing the CS_2 was of glass 49.65 long and 0.685" (1.74 cat. 0.463" (1.175) internal diameter. It was closed by 2 polished glass disks about 0.2 thick.

Test made 3rd Sept. 90.

The resistance of the coil at about 19°C was 203.4ω. It was filled with CS_2 and placed in the polarimeter. Two sodium burners were used. The coil was connected directly with the mains through a rheostat, the P.D. on the mains being 129.0 volts approx. by Wirt Voltmeter. The following observations were then made.

No. of Obs.	P.D.	Res.	Current	Rotation Minutes	Weight	Mean.	v	v^2	fv^2		Result
1	129	203.4	0.6343	+310	2		0.9	0.81	1.62	0.1231	313.6'
2				−318	2		5.4	29.16	58.32	× 13.24	± 1.63/2
3				+314.5	2					= 1.63	
4			0.625	−306	2	627.1/2	6.6	43.56	87.12		= 313.6 ± 0.8
5				+324	2		2.9	8.41	16.82		
6				−302	1		1.1	1.21	1.82		
7				Two mins. +324	1						
8	129	209.5	0.6158	−300	1		3.1	9.61	9.61		
9									17.231		

Marcant gives 0.04.15' as the constant for D in CS_2

To the first approximation therefore

$$\theta = 0.04.15' \times 1.257 \times 9600 \times 0.625$$
$$= 4.15' \times 1.257 \times 0.96 \times 6.25 \times 10'$$
$$= 313'$$

To find the terminal length correction h = 1.53

$$d_1 = 1.55 \qquad \rho_1 = \sqrt{\{(1.55)^2 + (1.53)^2\}} = \sqrt{(2.4025 + 2.3409)}$$
$$= \sqrt{(4.7434)} = 2.18$$

$$d_2 = 48.10 \qquad \rho_2 = \sqrt{\{(48.1)^2 + (1.53)^2\}} = \sqrt{(2313.6 + 2.34)}$$
$$= \sqrt{(2315.94)} = 48.12$$

$$\rho_2 - \rho_1 = 45.94$$

corrected $$\theta = \frac{313 \times 45.94}{46.56} = 308.9$$

The surface of the coil was 46.6 × 3.14 × 3.53 = 516.5 sq. cm.

energy developed per sec = 129 × 0.625 = 80.6 Joules

= 6.41 sq. cm per Watt.

Formula (9) becomes on simplification ($\rho = 1.7\times10^{-6}$ $\sigma = 8.95$)

$$\theta = \frac{2.5772}{10.67}\times10^{2}\,\varphi\sqrt{\frac{l\,m\,h}{a}}\cdot\frac{\pi}{1+X} \qquad (11)$$

For the D line φ is stated to be 4.15×10^{-2} by Mascart

$$\theta = \frac{1.607}{1.067}\times10^{5}\sqrt{\frac{l\,m\,h}{a}}\;\frac{X}{1+X} \quad \text{where } X = \sqrt{1+\frac{4m}{\pi q}\left(\frac{D}{d}\right)^{2}},$$

$$\theta = \frac{1.607}{10.67}\sqrt{\frac{l}{a}\,m\,h}\;\frac{X}{1+X} \qquad (12)$$

When used for intermittent and measuring currents h may be put $= 0.02$

$$\theta = \frac{1.607}{1.518}\sqrt{\frac{l}{a}\,m\,h}\times\frac{X}{1+X} \qquad (13)$$

When used for steady currents h may be put $= 0.01$

$$\theta = \frac{1.607}{1.067}\sqrt{\frac{l}{a}\,m}\times\frac{X}{1+X} \qquad (14)$$

The limit of $\sqrt{\frac{l}{a}}$ is probably 10 that of the fraction 1 and hence with 10 kgms. of wire, the limiting rotation is by (14)

$$\frac{1.607}{1.067} = 1.5 = 17^\circ.47'$$

In the experiment recorded on the preceding page, $h = 0.156$

$l = 46.56$, $a = 1.39$ $m = 565$ $X = 1.225$

So that $\theta = \frac{2.07}{10.67}\times\sqrt{\frac{46.56\times565\times0.156}{1.39}}\times\frac{1.225}{2.225}$

$$= \frac{1.607\times54.34\times1.225}{2.225}$$

$$= 31^\circ.5$$

When the heat limit cannot be reached owing to resistance in circuit so that $c = \frac{E}{\beta+r}$, these formulae do not hold. In such a case

Diff (2) $\theta = \frac{4\pi}{10}c\varphi\frac{l(b-a)}{D^2}$. Eliminating D in terms of m & r

$$D^2 = \pi l\,(b^2-a^2)\sqrt{\frac{\rho\sigma}{m r}} \quad \text{while } d^2 = \frac{4}{\pi}\sqrt{\frac{m\rho}{r\sigma}} \qquad (15)$$

whence $\theta = \frac{4\,c\varphi}{10(b+a)}\sqrt{\frac{m}{\rho\sigma}}$ and $= 0.0256\sqrt[4]{\frac{m}{r}}$ with $\rho = 1.7\times10^{-6}$

$0.0390\sqrt[4]{\frac{m}{r}}$ with $\rho = 1.8\times10^{-6}$

$$= \frac{4\varphi}{10(b+a)}\sqrt{\frac{m}{\rho\sigma}}\times\frac{E\sqrt{r}}{\beta+r}$$

$$\frac{d\theta}{dr} = J\left\{\frac{\frac{E}{2\sqrt{r}}(\beta+r)-E\sqrt{r}}{(\beta+r)^2}\right\}$$

for max $\beta + r = 2r$

or $r = \beta$

and $\theta = \frac{E\varphi}{5\sqrt{\beta}(b+a)}\sqrt{\frac{m}{\rho\sigma}}$

for copper $= \frac{E\varphi\sqrt{m}}{\sqrt{\beta}(b+a)}\times\frac{1}{2.0\times10^{2}}$

for D line $= \frac{E\sqrt{m}}{\sqrt{\beta}(b+a)}\times2.084$

$$= \frac{E}{\sqrt{\beta}}\sqrt{\frac{m}{a}}\times\frac{2.084}{1+\sqrt{1+\frac{4m}{\pi q}\left(\frac{D}{d}\right)^{2}}}$$

This is now nearly independent of the length.

To determine in this case the diameter needed, take (15)

$d^2 = 5.704\times10^{4}\sqrt{\frac{m}{\beta}}$

Conditions for securing the maximum indications from an optical galvanometer. contd. from page 99.

Let

c = the current in the helix (ampères).
e = " e.m.f. on " " (volts)
r = " resistance of " " (ohms)
R = " coiling space of " " (c.c.)
l = " length of " (cms)
a = " inner radius of " " (cms)
b = " outer " " (cms)
m = " mass of wire on " " (grammes)
n = " number of turns in " " per cms.
N = bn " " " " as a whole.
σ = " specific gravity of copper wire " " (8.95)
v = " difference of magnetic potential between ends of liquid column
θ = " rotation of the plane (in minutes of arc)
φ = " Verdet constant (minutes of arc) 0.01415' for D
d = " diameter of the wire (cms)
δ = " thickness of insulating covering (cms)
D = " diameter of covered wire (cms) $= d+2\delta$.
h = " energy dissipated in tube per sq. cm. surface (Watts).

Then

$$\theta = v\varphi = \frac{4\pi}{10}c\varphi N = \frac{4\pi}{10}\frac{e}{r}\varphi N \qquad (1)$$

$$N = \frac{l(b-a)}{D^2} \qquad (2)$$

$$r = \frac{4\rho l(b^2-a^2)}{D^2 d^2} \qquad (3)$$

$$\therefore\ \theta = \frac{\pi}{10}\frac{c\varphi d^2}{\rho(b+a)} \qquad (4)$$

but

$$b = a\sqrt{1+\frac{4mD^2}{\pi^2 l a^2\sigma d^2}}$$

$$= a\sqrt{1+\frac{4m}{\pi q}\left(\frac{D}{d}\right)^{2}} \quad \text{where } q = \pi a^2 \sigma l \text{ the mass of the core in copper.} \qquad (5)$$

$$\text{and } d^2D^2 = \frac{8hb\pi l^2\rho(b^2-a^2)}{c^2} \qquad (6)$$

$$\therefore\ d^2 = \frac{\sqrt{l}}{c}\sqrt{\frac{32h\rho m a}{\pi\sigma}}\sqrt{1+\frac{4m}{\pi q}\left(\frac{D}{d}\right)^{2}} \qquad (7)$$

$$\text{and}\quad \theta = \frac{\pi}{10}\frac{c\varphi l}{\rho\sqrt{a}}\frac{\sqrt{\frac{32}{\pi}\frac{hm\rho}{\sigma}}\sqrt{1+\frac{4m}{\pi q}\left(\frac{D}{d}\right)^{2}}}{\left\{1+\sqrt{1+\frac{4m}{\pi q}\left(\frac{D}{d}\right)^{2}}\right\}^{2}} \qquad (8)$$

$$\text{or}\quad \theta = \frac{4\pi}{10}\varphi\sqrt{\frac{lm}{a}}\cdot\sqrt{\frac{2h}{\pi\rho\sigma}}\cdot\frac{\sqrt{1+\frac{4m}{\pi q}\left(\frac{D}{d}\right)^{2}}}{1+\sqrt{1+\frac{4m}{\pi q}\left(\frac{D}{d}\right)^{2}}} \qquad (9)$$

This expresses the rotation obtainable from a given weight of wire and shows that the sensitiveness of the apparatus varies as $\sqrt{\frac{l}{a}}$ nearly and also approximately as $\sqrt{m}$.

d can then be obtained from (7). in terms of c, l, a & m

If the instrument is needed for an ammeter of maximum current c, Then

$$d^2 = \frac{c}{\pi}\sqrt{\frac{8\,am\rho}{hq\sqrt{1+\frac{4m}{\pi q}\left(\frac{D}{d}\right)^{2}}}} \qquad (10).$$

$$\theta = \frac{4\pi}{10}\frac{c\varphi l(b-a)}{D^2}$$

Std = 0.009833 @ 23.5°C 23.5 − 20.8 = 2.7°C × 0.021 = 5.67 × 10⁻²,

1 × 10⁻² ×

= 0.009827 @ 20.8° C.

$9.827 \times 10^{-3} \times \frac{2712.5 + 1265}{2712.5} = 1.441 \times 10^{-2}$ ω.

$\frac{1.441 \times 2.8776 \times 10^{6}}{5.977 \times 10^{2}} = 6.9186 \times 10^{3} = 6919$

Resistivity of copper @ 20.8C. 1.753×10^{3}

Conductivity = 25.33 %.

$0.009827 \times \frac{4085 + 2712.5}{2712.5} = 0.03623$ ω.

$0.03623 \times \frac{2712.5}{2712.5 + 1950} = 0.02108$ ω

$0.02483 \times \frac{2712.5}{2712.5 + 1950} = 0.01427$ ω.

$6919 \times 10^{3} \times \frac{2742.5}{2712.5} = K \times \frac{1.753 \times 0.06022 \times 10}{4.79}$

$\frac{1.441 \times 10^{-2} \times 2742.5}{2712.5} = 1.457$

$\frac{1.457 \times 10^{-2} \times 6.022 \times 10^{-2}}{4.79} = 1832 = 95.5\%$

$\frac{1.44 \times 10^{-2}}{5.977 \times 10^{2}} = 2.409 \times 10^{-5} \times 1.6093 \times 10^{5} = 3.877$ ω per mile

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Tests of a sample of "Tobin" Bronze Trolley Wire

(117)

A 25 foot sample of this wire # 4 B.W.G. was received 10th Sept. 90. Its conductance was tested the same day.

Hart: & Brown galv: 15 ω in rt. hand oil adjusts balance. Quite differential in series. Res: of both 5.425 ω. − 2712.5 each. Stretched the bronze wire along floor, and soldered two fine copper wires near extremities. Compared with Std: 0.01 ω whose temp: was observed to be 20.8°C. With about 8 amp: current, deflections 250 d. ± Balance with 1265 ω added to wire.

2nd Test. Half of platinoid grid balanced against holly wire. Balance obtained with 1950 ω added to grid.

3rd Test. Half of platinoid grid balanced against 0.01 ω Std: 4085 ω added to grid.

4th Test. Stretched a length of # 12 wire along floor (diam 0.109"), and included it in main circuit. Attached pressure wires near its extremities. Balanced with 30 ω added to bronze wire.

Length of Bronze wire by steel tape between pressure wires: 598.0, 597.5, 597.8 } Mean 597.7 cms

Diameter - - - - micrometer: 0.2385", 0.2385", 0.2383", 0.2395", 0.2386", 0.2380", 0.2377"

Mean 0.2383" = 0.6053 cm.

Length of copper wire 479 cms. Sq. cms. 0.28776 sq. cms. 0.04464 sq. ins.

Diam 0.109" = 0.2769 [illegible] sq. cms.

Length	Diam.	Area.	Resistance @ 20.5°C	Resistivity @ 20.5°C	Conductivity in terms of pure copper @ 20.8°	Resistivity of pure copper @ Sydney	Resistivity of pure copper @ 20.8° C.
597.7	0.6053	0.2878	0.01444	6919	25.3 %	1624	1753

The tensile strength was observed by straining the wire from a piston fully working in a cylinder of oil. A pressure gauge on the cylinder and also an indicator (Old Tabor) were connected. The wire was bent over ——— and wrapped with copper binding-wire finally soldered in. The wire broke close up to the solder, as in our looking. The diameter of the cylinder was 10" that of the rod 1.375

Area of cylinder 78.54 area of rod 1.4844 difference 77.056

At the moment of fracture the gauge showed 40 lbs. } mean 42.5
indicator 45.

45 × 77.06 = 3468 lbs. ÷ 0.04464 = 77,750 lbs. per sq. ⊡.

For ductility a length of wire was clamped in the vice and the opposite end twisted up by a wrench. On fracture 12 twists were counted by the ink line in 12".

Two samples were weighed as follow.

No.	Length	Weight	Weight.	gms per m.	Mean	Area	Sp. g.	Weight per	
1	38.9	3oz. 160 grains	94.13 gr	2.42	2.43	0.28776	8.44	3 qr 21 lbs	86 a lb.
2	62	5 - 150 -	151.5 -	2.44					

Test of the Safety Conduit Tubes that are mentioned on page 105.

These tubes were left in the tank on the roof under water, from the 21st Aug. to the 12th Sept. — 22 days.

The following are results with three.

#1. Both ends corked and carefully sealed with paraffine wax. G.P. wire penetrating through one seal. Tube full of water and in trough of water (tap water).

Insulation by bridge 100/000 Z to L. 20,000 ω. 360 per mile
C . . 17,000 ω. 306 . .

#2. Same conditions as #1 Z to L. 15,000 ω. 27 . .
C . . 12,500 ω. 22·5
Mean 32·5

Seals were examined and received. Test then repeated with same results.

One tube was then removed from the trough, the seals sawn off, and the tube emptied. Some cotton waste soaked in brine was then introduced near the middle of the tube with a wire in it. The outer surface of the tube was next dried, and covered at the ends with a coating of paraffine wax. A jacket of waste soaked in brine was then laid on about the spot occupied by the waste inside, and the resistance from interior to exterior measured. The resistance was about 100,000 ω and the space covered about one foot long.

#3. Was sealed at one end. Being somewhat bent it was laid in trough with both ends projecting. It was covered with water only at its middle. Water was poured inside and a copper wire inserted for contact with this water. The exterior of the tube was dried. Res: between water in trough and water in tube about 70,000 ω.

Approx. Tubes dimensions Length 9' 6". Int: diam 1" Ext: diam 1⅞".

Measurement of Temperature supplied by Lalande Battery Solution before freezing, by Messrs Thompson & Glaisworth.
14th September 1880.

About 25 c.c. of solution of regular battery NaHO sp.g. 1·25 was cooled by freezing mixture. The lowest temperature reached was −16° C and there were no signs of freezing at that point.

Meteorological Records

Date		Barometer Readings Inches			Barometer Readings Inches at 0° Cent.	Thermometer Readings Max.	Min.	Dry	Wet	Rain &c. in 24 hrs.	Wind & Weather	Remarks.
Sept	13	29.493	75.42	74.0	29.527	80°	74°	80°	77°	1.02	S	Raining.
	14	29.907	75.48	67.0	29.806	71.0	62°	67.0	65.0	.9	N.W.	Fair.
	15	29.845	75.81	67.0	29.782	78°	60	70	67	.23	S.W.	Cloudy Overcast
	16	29.739	75.54	70°	29.625	73	66	68	68	1.15	S.W.	Heavy Overcast
	17	29.609	75.21	67°	29.509	71	64	65	64	.21	S.W.	Rain.
	18	29.391	75.66	67.0	29.621	71	56	66	64	.10	W.	Overcast
	19	29.815	75.87	68°	29.767	77	52	68	66		S	Fair
	20	29.845	75.71	70°	29.711	72	61	70	67		S.W.	Fair. Cloudy
	21	29.717	75.72	62°	29.722	72°	62°	63°	62°		S.W.	Overcast
	22	29.767	75.32	63°	29.768	72°	53°	66°	62°		S	Fair
	23											
	24	29.935	76.08	64°	29.850	70°	57°	57°	57°		N.W.	Fair.
	25	30.066	76.34	60°	29.982	69°	52°	57°	57°		S	Fair
	26	29.783	75.50	60°	29.447	64°	52°	62°	61°		S	Fair
	27	29.767	75.42	60°	29.635	70°	57°	67°	66°	.45	S.E.	Raining Overcast
	28											
	29	30.067	76.34	55°	29.988	63°	48°	57°	57°		N	Fair
	30	29.997	76.26	60°	29.913	66	41	57	57		N	Fair
Oct	1	30.025	76.23	60°	29.933	69°	50°	65°	60°		N	
	2	30.027	76.23	60°	29.923	70°	50°	65°	63°		N.E.	Cloudy
	3	29.763	75.66	60°	29.665	70°	62°	67°	67°	1.01	N.W.	Overcast Raining
	4	29.607	75.51	67°	29.502	70°	55°	67°	65°	.63	S.W.	Fair
	5	29.541	75.09	64°	29.537	71	57	67	65°		W	Fair
	6	29.725	75.07	64°	29.681	70	54	57	57	.05	N.W.	Raining Overcast
	7	29.579	75.13	61°	29.472	58°	50°	53°	53°	.43	N.	Raining Overcast
	8	29.817	75.81	60°	29.730	62	51	56	55	.13	W.	Fair
	9	30.019	76.25	60°	29.935	64°	40°	54°	52°		W.	Fair.
	10	29.897	75.79	63°	29.774	67°	43°	62°	61°		S	Overcast
	11	29.725	75.50	70°	29.585	66	55	60	57		W	Overcast
	12	29.493	75.12	60°	29.609	62	50	54	53			Overcast
	13	29.725	75.81	64°	29.669	55°	41°	51	50	.01	N.W.	Fair
	14	29.524	75.01	75°	29.400	57	52	55	55	.11	N.W.	Raining Overcast
	15	29.767	75.59	61°	29.660	57	43	57	56	.14	W	Fair
	16	29.865	75.84	77°	29.730	63	46	66	58		S	Overcast Fair
	17	29.517	74.59	67°	29.412	63	54	58	55	1.05	S.W.	Fair
	18	29.733	75.53	68°	29.637	63	46	55	53		S.W.	Fair
	19											
	20	29.503	74.94	76°	29.391	60	49	52		.05	N.W.	Overcast
	21	29.795	75.81	76°	29.663	55°	43°	51°		.03	N.W.	Fair
	22	29.765	76.03	72°	29.645	53	39	49			N	Fair
	23	29.949	76.05	73°	29.820	53	43	47			N	Fair Clouded
	24	29.387	74.65	72.0°	29.267	55°	41	54°		1.50	N.W.	Rain Clearing
	25	29.537	75.05	76°	29.405	50	43	48		.18	N.W.	Rain
	26											
	27	29.271	74.36	73	29.148	52	40	48			W	Fair
	28	29.495	74.47	78	29.357	51	40	40			S.W.	Fair
	29	29.173	74.11	77°	29.038	47	39	47		.07	S.W.	Rain
	30	29.471	74.91	73°	29.348	48	38	47		.105	S	Overcast
	31	29.733	75.33	65°	29.698	58	38	44			S	Fair
Nov	1	29.915	75.21	73°	29.672	47	35	46			S.W.	Fair
	2	29.503	74.55	60°	29.419	44	37	48			S	Fair
	3	29.587	74.16	76°	29.455	53°	40°	46°			S.W.	Fair
	4	29.633	73.32	76°	29.531	43	36	41			S.W.	Overcast
	5	30.031	76.28	76°	29.899	45	30	45			S	
	6	29.977	76.26	76°	29.895	50	35	50			S	Fair
	7	30.005	76.26	79°	29.864	55	43	53		.002	S.	Overcast.
Omitted	8											
	9											
	10	29.959	76.073	75°	29.550	65	40	61	50		NNW	Overcast
	11	30.058	76.163	74°	29.929	56	35	41	41	0.28	N	"
	12	30.048	76.343	74°	29.916	44	34	40°	42°	0.09	N	Fair
	13	29.913	76.013	70°	29.797	48	34	46	45		W	"
	14	29.911	76.003	62°	29.821	53	40	54	53		W	"
	15	29.943	76.083	71°	29.826	55	36	53	51		S.W.	"
	16											
Omitted	17	29.709	75.493	75°	29.580	53	40	51	51	0.24	S.S.W.	Rains & Overcast
	18	29.709	75.493	71°	29.595	62	51	52	50	0.06	NE	very fair
	19	29.554	75.052	78°	29.399	53	38	52	50		W	overcast
	20	29.845	75.153	70°	29.461	58	35	41	39		N.W.	fair
	21	29.919	75.023	72°	29.788	46	34	38	36		N.E.	Fair fair
	22	29.754	75.213	70								
	23	29.949	75.03	70								
	24	29.949	75.103	70	29.835	45	24	43	32		NW	Fair
	25	29.574	75.163	70	29.638	50	38	50	48		W	Hill
Omitted	26											
	27	29.919	75.773	75	29.690	53	35	29	27		N	Fair

Plan of Switch 1/20
30ft = 1"
Plank 4.8.1.
Radius 500
Radius 1000
Radius 2000
Radius 3000
Radius 4000

Traction Experiments at Schenectady.

15th Sept. 20

Experimental grade 6%. Distance of poles apart 50 feet.

Experimental truck operated by 2 Sprague motors with all the usual outfit and connections except the trolley.

Experimental trailer. a flat truck weighing 11000 lbs loaded with 10 cons of weight now each 9½" diam and 57" long) brake at each end. At 1000 lbs end total load = 11,000 lbs.

1st trial. 200 ft. up grade in 17 secs. = 12 ft per sec. = 8.2 miles per hr. operated at full power of motors (in parallel). Starting pull delivered to trailer 3000 lbs. Mean pull 900 lbs. = 20 HP at trailer.

2nd trial 200 ft up grade in 16 secs = 12.50 ft per sec = 8.52 miles per hr. operated at full power of motors. Starting pull 4500. Mean full on grade 600 lbs = 13.50 HP. at trailer.

3rd trial Started on commencement of grade. Running on 2nd mark of switch. 100 ft in 12 secs. = 8.34 ft per sec = 5.6 miles per hr. Starting pull 10,000 lbs. mean pull 800 lbs = 12 HP. at trailer.

4th trial Stopped on descent of grade. Dynamometer indicating 600 lbs

Theoretical amount 0.06 x 11,000 − 5.5 x 15 = 660 − 82.5 = 577.5 lbs.

taking 15 lbs tractive friction per ton.

5th trial. Started on grade (?) with brakes down. Starting pull 3200 lbs

Mean pull not known.

6th trial. Changed trailer for an empty coal freight car weight 21,000

Pulled same at full power up grade. Max. at start 8500 lbs.

Mean pull on grade 750? Time not observed.

16th Sept.

Pull of coal freight car 21,000 lbs. on level 8 miles per hr. = 500 lbs.

" " " " " " up grade 2000

2nd trial. Run up grade (Wheels slipping). Pull 1100 to 1500 lbs Time 100 feet in 29 secs. = 3.45 ft per sec = 2.38 miles per hr.

Starting pull 10,000 lbs.

3rd trial Full speed up grade 16 secs for 200 feet = 12.5 ft per sec. = 8.5 miles per hour. Mean pull 1200 lbs Max. 5500

4th trial Stopped on grade. Pull 990 lbs

Theoretical amount 21,000 x 0.06 − 5.5 x = 990

5.5 x = 1320 − 990 = 330

x = 60

5th trial Started up grade. pull 2000 lbs. reducing to 1500 Max 2200

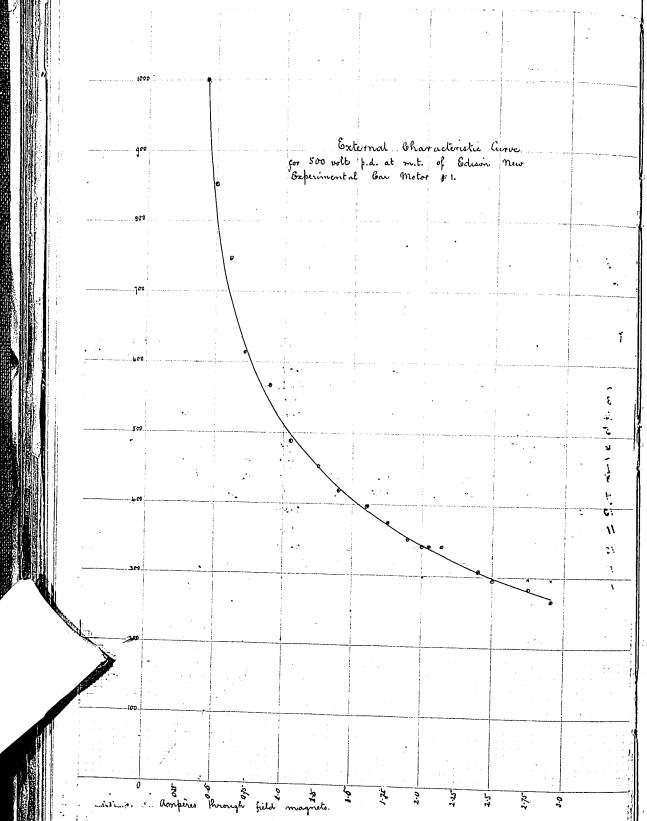
This run at full speed.

6th trial Came up grade on 2nd point of switch = 20 secs for 100'

1600 − 1300 lbs. pull. 5' per sec. 3.4 miles per hr.

7th trial Coming up on 2nd point of switch = 18 secs for 100'

1400 − 1200 lbs. pull.



Test of New Edison Experimental Car Motor #1.

Schenectady. 15th Sept. 1890

Resistance of armature between brushes
" field magnets 8 in series

A large ~~wooden~~ pulley was placed on one end of the shaft, and a belt taken to another dynamo, intended to absorb power. The fields of this dynamo was not excited so that the power absorbed by the motor had only to overcome the electrical and mechanical friction of its own armature and the mechanical friction of the armature.

The following observations for magnetic saturation were first made.

No. of Obs.	P.D. on Fields	Current in fields	P.D. on armature	current in armature	Speed Revs per min	Speed Reduced to 500 volts on mt.			
1	600	2.92	600	–	320	267			
2	550	2.75	550	–	310	282			
3	500	2.5	500	–	295	295			

The armature was next operated from the 220 volt circ: and the fields from the 500 volt machine with following results.

No. of Obs.	P.D. on fields	Current in field circ.	Energy in field circ. watts	P.D. on armature terminals	Current in armature circuit	Energy in armature watts	Energy per ampere per minute	Speed revs per min.	Speed revs per min. reduced to 500 volts	Fall of potential in armature	Direction of Rev. loc.
1	600	2.92	1750	220	1.8	396	2.27	130	296		
2	560	2.75	1540	"	1.8	396	2.27	120	296		
3	488	2.4	1170	"	1.8	396	2.99	135	307		Start.
4	435	2.14	932	"	1.8	396	2.64	150	341		
5	418	2.00	836	"	1.9	418	2.78	150	341		
6	425	2.05	871	"	1.9	418	2.78	150	341		
7	375	1.9	712	"	2.05	451	2.91	155	352		
8	355	1.75	621	"	2.05	451	2.73	165	375		
9	328	1.60	525	"	2.05	451	2.58	175	398		
10	285	1.4	399	"	2.1	462	2.50	185	420		
11	252	1.25	315	"	2.1	462	2.31	200	454		
12	215	1.05	226	"	2.3	506	2.35	215	488		
13	178	0.90	160	"	2.5	550	2.20	250	568		
14	148	0.77	114	"	3.3	704	2.61	270	613		Medium
15	125	0.62	77.8	"	4.0	880	2.67	330	749		
16	110	0.5	55	"	5.3	1166	3.11	375	851		
17	87	0.43	37.5	"	7.0	1540	3.50	440	1000		Fast.

18 530 2.4 1272 – Temp. on field (One hour's application field + armature 42°C. in 23° air 21°C.)

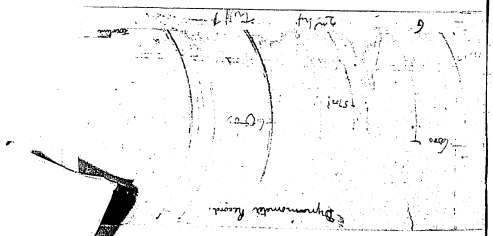
19 50 amperes (falling to 48) delivered to lamp bank through armature (with) continuously for half an hour. Fields not excited. Temp. on armature surface 72°C., Air 23°

Weight of complete motor (including girders 3 ft 6 ins. :- Armature & shaft 790
Fields complete 2480
Armature & pulley 497
3767

Test on 16th Sept. Motor running for one hour 530–600 volts p.d. about 49 amperes 26,000 to 29,400 Watts. Temp. on armature 76°C. Room 25°C. Fields at full pressure, Speed 295.

Checked dynamometer as follows –

A ~~cast~~ iron heifer 82·5 × 33·5 × 26·2 or 72,410 c.c. weighed by scales 1272 lbs
577 kgrs = 7.967 cwt. weighed on dynamometer indicated 1250.



Test of Magnetic Clutch Power – Preliminary.
at Schenectady 16th Sept. 90.

No. of Obs.	No. of Clutch	Current in clutch	P.D. on Clutch	Energy in Clutch	Weight employed	Dist. off centre feet	Torque	Pull at one weight pounds	
1	1	50	1.25	62.5	105 lbs.	4.5	473	280	
2		40				4.4	462	284	
3		30				3.5	368	295	
4		20.5				3.0	315	252	
5		9				1.5	157	1~~50~~	
6	2	50				3.5	368	293	
7		39				2.8	294	240	
8		30				2.5	262	208	
9		20				2.0	210	168	
10		10				1.4	147	120	

Traction Experiments at Schdy.
Synopsis of Results.
18th Sept. 90.

Trip	Obs.	Pole.	Time	Rate ft per sec	Switch	Amperes	Volts ※	Power Watts	Pull	Weight moved	Energy expd. mechly	Efficiency	Rate miles per hr.	Tractor Wt	Motor Gen Wt.
1	1	8	37	9.1	Full.	32	520	16,640	700					21,000 +3×200 +800 +100 29,250	3200 1100 700 5,000 18,400 29,600
	2	7	48	10		34	510	17,340	600						
	3	6	58	16.7		20	520	10,400	200						
	4	5	64	11.4		14	520	7280	0						
	5	4	71	11.3		30	510	15,300	80						
	6	3	80	11.1		83	480	39,840	1500						
	7	2	92	8.3		85	475	40,375	1400	39,650					
	8	1													
2	1	8	39	8.3	Full	30	520	15,600	Not	10,500			–		
	2	7	51	12.5		15	520	7800	observed						
	3	6	59	14.3		11	520	5720							
	4	5	66	14.3		50	520	26,000							
	5	4	73	14.3		34	520	17,680							
	6	3	80	14.3		38	520	19,760							
	7	2	87	14.3		29	520	20,300							
3	1	8	.0	5.5	Full	28			500	39,650					
	2	7	19	11.1		35			700						
	3	6	29	7.1		25			250						
	4	5	44	14.0		14			0						
	5	4	69	2.5		31			1200						
	6	3	108	7.7		82			1500						
	7	2	121	9.1		86			1700						
	8	1	132			0			0						
4	1	7	40	14.3	Full	30	520	15,600	Not	10,500					
	2	6	47	20		27	520	14,040	observed						
	3	5	52	25		20	520	10,400							
	4	4	56	12.5		25	520	13,000							
	5	3	64	12.5	rev.	34	520	17,680							
	6	2	72	14.3		38	520	19,760							
	7	1	79			0	520	-							
5	1	4	–	–	stopped	–	–	–	1550 lb	pull of	brake				
	2				Shorted	86 to 100	475	47,500	1900						
	3				-	60	490	29,400	–	with not	heater				
	4					50									
	5					40									
	6					35									

※ These numbers are 20 in error.

wire	armature	wire	
0·043	0·043	0·043	48 sections wire brush on 2
0·043		0·043	

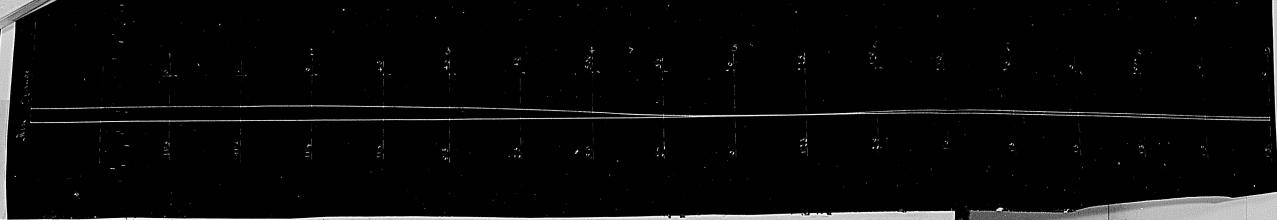
wire	armature	wire	
0·056	0·043	0·056	48 sections wire brush on 2
0·056		0·056	

brass	armature	wire	
0·186	0·043	0·056	24 sections wire brush on 1 or on 2

Experimental Car Inch.

?

Sayreschby Works. Sept 20th 1900.



Sparking Experiments.

Sept. 20.

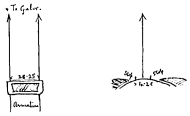
Comparison between two # 4 armatures successively placed in the same field. Armature #1 was of the ordinary standard type. With the fields at 125 volts and no load, the brushes could be shifted 3/16", without excessive sparking from the neutral line, or mid (blocks. With the full load of 80 amperes on the machine (dynamo 1620 rev.) the neutral line shifted 3/16" of an inch or the permissible previous limit, and could be moved again from this point 3/16" of an inch on either side without excessive sparking. Brush reading on 2½ bars. Exceeding these limits very heavy sparking resulted.

Armature #2 had g.s. connecting wires to the commutator. The res. of each wire was 0.0425 or 12 × res. of one coil = 1 × res. of armature with brush on 2 bars. When field excited and no load, there was very little sparking all round the commutator. The brushes could be set at the centre of e.m.f. without any (very) heavy sparking. On connecting up to a circuit and running as a dynamo the neutral line shifted on full load 3/16" and any position of the brushes could be tolerated. 125 volts.

When run as a motor, the sparking was much heavier, there with fields 70 volts + 50 amperes load. Driving engine running as motor, an excursion of only 2" could be tolerated. The limit reached was not so much the sparking as the heating of the g.s. wires. With fields 125 volts + 20 amperes motor load there was also heating of the wires.

The german silver wires were next cut, so as to double their resistance and halve their area. This produced a still greater immunity from sparking. The excursion tolerated from the neutral point was 2½". with 20 volts on the fields + 80 amperes.

The (single) german silver wires were then halved in number, and the bars doubled connected in pairs. This made the sparking much worse. The range permissable with no load running as a motor on 125 volts was 1⅞". On applying full load at 125 volts the range was only 1" and there was some point of complete sparklessness. This condition was not much exaggerated however when the p.d. was reduced to 20 volts.



Res. of Galv 6,200 ω.

$$118{\cdot}65\ H = d \times 1{\cdot}8411 \times 10^{-10} \times 6{\cdot}2 \times 10^{12}$$

$$H = 10\ d.$$

If v be the peripheral velocity $= \pi d n v$

$d = 60{\cdot}8 \quad \pi d = 190{\cdot}9$

and b be the mean breadth of wire

Then the emf. in the section under the brush is

$$2n\ b\ H \times 190{\cdot}9\ v = 2n \times 20 \times 190{\cdot}9\ v H$$

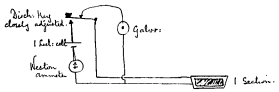
$$e = 1{\cdot}375 \times 10^5\ v H$$

If $H = 400 \qquad = 5{\cdot}5 \times 10^7\ v$

Standard Daniell solution

$CuSO_4$ 1·26

$ZnSO_4$ 1·16



Motor Determinations at Schenectady

September 22nd

(124)

Connected a wire vertical rectangle over the motor armature so as to be movable parallel to itself along the armature periphery. By limiting the motion to three sections, accelerating its motion with elastic bands, and connecting up to a Thomson galvanometer the normal component of the armature field was determined.

	Capacity of bands.	Estimated value of Sec. ult. Deull	Throw	a	a per div:				
	$\frac{1}{3}$ ℓ	1·05	±190 div.	$3{\cdot}5 \times 10^{-7}$	$1{\cdot}8411 \times 10^{-10}$				
Obs.	Current in field. amps.	Current in armature amps.	Observed throw.	Mean	Mean normal component	Dimension wire.	emf. at 2·20 ωm. volts	emf. at 4·60 ωm volts	emf. @ 700 ωm. volts.
1	2·5	0	−1	−1					
2	"	48	42 35 37 37	38	380	28·25 cm length + 4·2 cm of throw. = 118·65 sq. cm.	2·05.	4·10	6·25
3	0·7	50	43 38 38 36	39	390				
4	0	50	32 35 32 37	34	340				

To determine the inductance of the sections, one of them was disconnected, and brought out. Wire from its terminals were connected up with the galvanometer and discharge key as shown.

With a current of 0·173 amp: the discharge was 15 divs:

Let e be the emf. in a circuit

r . its res:

l . its inductance

c - its flow

Then on removing e, the equation of motion is

$$l\frac{dc}{dt} + cr = 0$$

$$\frac{dc}{dt} + \frac{c}{T} = 0 \qquad \text{if } \frac{l}{r} = T$$

$$\therefore c = \kappa\, \varepsilon^{-\int \frac{dt}{T}}$$

$$= \kappa\, \varepsilon^{-\frac{t}{T}}$$

when $t = 0$ $c = C$ $\therefore \kappa = C$

$$c = C\varepsilon^{-\frac{t}{T}}$$

$$dq = C\varepsilon^{-\frac{t}{T}}\,dt$$

$$q = C\int_0^\infty \varepsilon^{-\frac{t}{T}}\,dt$$

$$= CT = \frac{Cl}{r} \qquad \therefore l = \frac{rq}{C}$$

$$q = C\int_0^\infty \varepsilon^{-\frac{t}{T}}\,dt = -CT\varepsilon^{-\frac{t}{T}} = -CT\left(\varepsilon^{-\frac{\infty}{T}} - 1\right)$$

In this case $r = 6{\cdot}2 \times 10^{12}$ $\quad q = 15 \times 1{\cdot}8411 \times 10^{-10}$ $\quad c = 1{\cdot}73 \times 10^{-2}$

$$\therefore l = \frac{6{\cdot}2 \times 1{\cdot}5 \times 1{\cdot}8411}{1{\cdot}73} \times 10^5 = 9{\cdot}9 \times 10^5 = 9{\cdot}9 \text{ kilometres.}$$

For this particular motor, the armature res. being 1·33, equivalent to $\frac{32}{4}$ blocks $= 0.166\ \omega = 1.66 \times 10^{5}$

$$L = 9.9 \times 10^{5}$$

$$T = \frac{9.9 \times 10^{5}}{1.66 \times 10^{8}} = 6 \times 10^{-3} = 0.006 \text{ seconds.}$$

$$\theta = \frac{2}{128\,n} = \frac{1}{n \cdot 64} = \frac{1}{18.66 \times 64} \quad \text{for } n = 18.66$$

$$= \frac{1}{746}$$

$$= 0.001134.$$

$$\frac{\theta}{T} = \frac{0.001134}{0.006} = 0.223$$

$$\varepsilon^{\frac{\theta}{T}} = 1.26$$

$$\frac{1}{\varepsilon^{\frac{\theta}{T}}} = 0.794$$

$$1 + \varepsilon^{-\frac{\theta}{T}} = 1.794$$

$$1 - \varepsilon^{-\frac{\theta}{T}} = .206$$

$$\frac{1+\varepsilon^{-\frac{\theta}{T}}}{1-\varepsilon^{-\frac{\theta}{T}}} = 8.7$$

$$C = 1.25$$

$$\sigma = 8.7 \times 1.25 = 10.9 = 109 \text{ amp.}$$

$$e = 18 \text{ volts active in opposite direction } 6$$

At slow speed. $\frac{\theta}{T} = 0.67$

$$\varepsilon^{\frac{\theta}{T}} = 2$$

$$\varepsilon^{-\frac{\theta}{T}} = 0.5$$

$$\frac{1+\varepsilon^{-\frac{\theta}{T}}}{1-\varepsilon^{-\frac{\theta}{T}}} = 3$$

$$C = 1.25$$

$$\sigma = 3.75 = 37.5 \text{ amp}$$

$e = 6.3$ volts. volts active in opposite direction 2.

Assuming 4 times as many sections in the armature, $T = 0.04415 \times 10^{-3}$

$$= 4.15 \times 10^{7}$$

$$\frac{L}{T} = \frac{9.9 \times 10^{5}}{16 \times 4.15 \times 10^{7}} = 0.00149$$

$$\theta = 0.00113$$

$$\frac{\theta}{T} = 0.9$$

$$\varepsilon^{\frac{\theta}{T}} = \varepsilon^{0.9} = 10^{0.391} = 2.47$$

$$\varepsilon^{-\frac{\theta}{T}} = 0.405$$

$$\frac{1+\varepsilon^{-\frac{\theta}{T}}}{1-\varepsilon^{-\frac{\theta}{T}}} = \frac{1.405}{0.595} = 2.36$$

$$C = 1.25$$

$$\sigma = 2.36 \times 1.25 = 2.95 = 29.5 \text{ amp.}$$

$$e = 1.2$$

Determination of the equations of motion in a dynamo or motor segment under a brush.

(125)

Let n be the number of revs: per second.

- H - - normal mean field at the neutral point.
- $\mathfrak{B}$ - - number of sections in the armature.
- ϖ - - - - wires in the section.
- c - - current in the section at any time abs.
- $\mathcal{C}$ - - - in the armature sections abs.
- r - - res: of the section abs.
- ρ - - external res: to the section abs.
- L - - inductance of the section emu.
- b - - mean breadth of armature wires.
- e - - e.m.f. generated in it by closing cct.
- D - - diameter of the armature.
- h - length of brush surface, j be length of bar + mica thickness

Then $e - L\frac{dc}{dt} - c(r+\rho) = 0$

$$\frac{dc}{dt} + \frac{c}{T} = \frac{e}{L} \qquad \text{where } T = \frac{L}{r+\rho}$$

$$c = \varepsilon^{-\int \frac{dt}{T}}\left(\int \varepsilon^{\int \frac{dt}{T}} \frac{e}{L}\, dt + K\right)$$

$$= \varepsilon^{-\frac{t}{T}}\left(\frac{e}{L}\int \varepsilon^{\frac{t}{T}} dt + K\right)$$

$$= \varepsilon^{-\frac{t}{T}}\left(\frac{e}{L} T\, \varepsilon^{\frac{t}{T}} + K\right)$$

$$= \frac{e}{r+\rho} + K\, \varepsilon^{-\frac{t}{T}}$$

when $t = 0$ $\quad c = \mathcal{C}$

$$\mathcal{C} = \frac{e}{r+\rho} + K \qquad \therefore K = \mathcal{C} - \frac{e}{r+\rho} = \mathcal{C} - \sigma$$

when $t = \infty$ $\quad c = \frac{e}{r+\rho} = \sigma$

$$c = (\mathcal{C} - \sigma)\,\varepsilon^{-\frac{t}{T}} + \sigma$$

$$= \mathcal{C}\,\varepsilon^{-\frac{t}{T}} + \sigma\left(1 - \varepsilon^{-\frac{t}{T}}\right)$$

$$e = \varpi\, 4 H \pi n D$$

$$t = \frac{2}{\pi n} \text{ approximately for a 2 bar brush or } \frac{h - (j - m)}{\pi n} \text{ accurately}$$

To completely overcome sparking we must have at time $\frac{2}{\pi n}$ or θ

$$-\mathcal{C} = \mathcal{C}\,\varepsilon^{-\frac{\theta}{T}} + \sigma\left(1 - \varepsilon^{-\frac{\theta}{T}}\right)$$

$$\sigma = \frac{\mathcal{C}\left(1 + \varepsilon^{-\frac{\theta}{T}}\right)}{1 - \varepsilon^{-\frac{\theta}{T}}}$$

Standard Sprague Motors

Style 17	Total Weight of wire on Magnets	Weight of wire on armature	Total cost of wire.		Lbs wt per H.P.	Lbs wt. complete Total weight
1/2	15 lb	2.9 lb	13	00	260	348
1	22 "	4.5 "	14	62	202	271
2	32 "	9.6 "	21	85	164.5	221
3	50 "	13.6 "	29	35	146.7	196.7
5	76 "	21 "	38	00	137.8	184.7
10	100 "	18.3 "	44	50	100.5	134.7
15	166 "	36 "	74	05	96.8	129.8
20	226 "	68.5 "	104	81	96.2	122.3
25	340 "	86.5 "	147	50	137	183.7
35	410 "	102 "	183	10		
50	578 "	169 "	265	75		
75	800 "	252 "	371	00	156	209.1

C. F. Hy.

1.05 watt × 0.33 f = 0.35 × 10^-7 Q gauss 178 dim.

1 dim = 1.67 × 10^-10 V

$l = \frac{Vy}{2} = \frac{6.3 \times 10^{-10} \quad q = 3.0 \times 10^{7} \times 1.67 \times 10^{-10}}{2.7 \times 10^{-3}}$

$= \frac{1.86 \times 1.067}{2.7} \times 10^{4}$

$= 1.355 \times 10^{4}$

$= 13.55$ kilomilles.

$q = 9.5.3 \times 1.067 \times 10^{-10} = 1.01.5 \times 10^{-10} = 1.075 \times 10^{-8}$

$f = 106.200 \times 10^{3} = 1.062 \times 10^{10}$

$f = 1.075 \times 1.062 \times 10^{6} = 1.991 \times 10^{6}$

Time of one revolution is 3.182 × 10^6 sec. for 5700 revs @ 2.25 mph

$q_{\text{mag}} = 4.96 \times 10^{6}$

$f = \frac{4.96 \times 10^{10}}{5.333 \times 3.075 \times 10^{6}}$

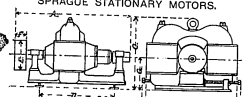
$= 3.025 \times 10^{6}$

$v = \frac{3.1.82}{3.025} = 1.315$ ~ Lenz = 23.67 ft/sec

$\phi = 9.260$ sec. the same @ 2.25

No. B. W. Gauge.	Diameter in Mils.	Circular Mils d 2.	Pounds per 1000 ft.	Feet per Pound.	Ohms per 1000 ft.	Feet per Ohm.
4/0	454.	206116.	623.84	1.6030	.050368	19854.
3/0	425.	180625.	546.75	1.8290	.057471	17400.
2/0	380.	144400.	437.08	2.2879	.071891	13916.
0	340.	115600.	349.90	2.8579	.089802	11136.
1	300.	90000.	272.41	3.6709	.11535	8669.6
2	284.	80656.	244.13	4.0962	.12871	7769.5
3	259.	67081.	203.04	4.9251	.15476	6461.8
4	238.	56644.	171.46	5.8325	.18327	5456.5
5	220.	48400.	146.50	6.8259	.21448	4662.4
6	203.	41200.	124.73	8.0171	.25191	3969.7
7	180.	32400.	98.070	10.197	.32040	3121.1
8	165.	27225.	82.405	12.135	.38131	2622.6
9	148.	21904.	66.299	15.083	.47394	2110.0
10	134.	17956.	54.349	18.400	.57815	1729.7
11	120.	14400.	43.586	22.944	.72092	1387.1
12	109.	11881.	35.961	27.808	.87378	1144.5
13	95.	9025.	27.318	36.605	1.1502	869.41
14	83.	6889.	20.853	47.965	1.5068	663.64

DIMENSIONS, WEIGHTS AND OTHER DETAILS OF SPRAGUE STATIONARY MOTORS.



H. P.	A.	B.	B_2.	C.	D.	E.	F.	G.	Speed.	Weight in Lbs. Net.	Shipping.
¼	14⅛		11⅛	7⅞		2½	1⅜	3½	2000	54	66
½	20	17⅞	13⅞	12¾	11⅞	2⅝	2	6¼	1900	130	230
1	22⅝	17⅞	16¾	14⅝	13¼	4⅛	2½	7¼	1800	202	322
2	26¾	19	20	16⅝	15⅞	5	3	7½	1650	320	479
3	31⅛	19⅞	22½	18⅛	19½	6	3½	8⅞	1650	440	600
5	34	21¼	25⅝	22¼	20¾	8	4	11	1400	689	915
7½	37	21⅝	27½	24⅛	22⅝	8½	5	11½	1300	854	1097
10	39	22¼	30⅝	24⅝	25	9	6	12½	1200	1005	1329
15	45½	22½	33⅝	28¼	28½	10	7	12⅞	1200	1452	1961
20	49¾	24	36⅝	29⅝	29¾	11	8	14	1100	1824	2256
25	56½	25	41½	32¾	33¾	12	10½	15¾	850	3419	3792
35											
50											
75	80¼	46	62	54⅛	51⅝	24	12	26½	500	11863	13652

The speed of the ¼ H. P. motor, as given, is with full load.
Speeds of all machines vary somewhat from table. On this account, driven pulley should not be put on shaft until motor card, giving exact speed of machine, has been received.

Measurements of the inductance and induction in the car motor.

Schenectady 23rd Sept. 20.

Repeated measurement of inductance of one section. An attempt was made to determine how this varied with the variation of current in the field or armature. But owing to the unsteadiness of this current, this failed. Recourse had therefore to be made to the simple inductance of the section unmagnetised.

Mean current ·0.27 amp. Mean throw on release of key 30 divs. 1.05 volts × 0.33 ~~f~~ = 17⅞ divs. Mean inductance

Wrapped one turn of wire round a single core, near the brass plate. This turn was led to the galvanometer through 100000. With 2.25 amps. in field, made throttle but not reversed the mean throw was 95.3. divs. the mean induction

Schenectady

Trial of the Clutch after enlargement and reboring

Current 43 amperes 370 lbs (8½" × 6½" × 22¾" keyway ⌀6) supported at a radius of 42½". This is a moment of 15,730 inch-pounds at 1" or 1050 lbs applied to the periphery of the 30" car wheel. The two clutches should therefore give 2100 lbs at the available pull with 43 amperes.

Orange 24th. IX. 90

Trial of the Carrying Capacity of platinoid wire.

Two wires were tried, of platinoid, one 0.032" the other 0.013" diam. 21 B&S. These were tested for their carrying capacity, supported horizontally in air. The larger carried 6 amperes at a temperature say 20°C, and the smaller 2.5 amperes. By our tables this is quite to be expected.

Particulars concerning different types of small Motors.

Name	Power	Weight	Wt. per hort	Speed Revs. per min	Speed × Wt per hort.	Wire on armature	Wire on field.		
Sprague		202		1800		4.9	21		
Edison	1000	270	270	2100		3.9	28		
"	5000	830	166	1800		20.1	51		
G.W.	1000	162	144	1060		6½	9¾		
	5000	475	95	900		16	20		
Sedg. Quad	2500	–	–	1600		4	50		

Calculation of the Diameter of German silver wire necessary to safely connect the armature and commutator in the Experimental Car Motor # 1.

Basis assume the brush to always rest upon two and only two bars, that full load is 50 amperes, that four brushes are used, and that the convection is ~~[illegible]~~ for still air with 80° rise:

There are 512 sections wire with 4 brushes, 12 active at any one moment or each is active 1/43 rd of the time.

Let d = the diameter of the wire (cms)

" r = " resistivity " " (ohms) at working temp.

Its res: per cm: is $\frac{4r}{\pi d^2}$

The energy developed by a current of c amperes per cm: in one second =

$$\frac{1}{43} \times \frac{4c^2r}{\pi d^2}$$

The radiation per cm = $0.0577\,\pi d$ Watts

" convection " " = 0.00175×80 = 0.14 Watt.

$$\therefore \frac{4c^2r}{43\,\pi d^2} = 0.0577\,\pi d + 0.14$$

$$\frac{4c^2r}{135.1\,d^2} = 0.0577\,\pi d + 0.14$$

$$4c^2r = 7.795\,\pi d^3 + 18.91\,d^2$$

$$= 24.5\,d^3 + 18.9\,d^2$$

Approximately $d^2 = 0.2116\,c^2r$

$$r = 21 \times 10^{-6}$$

$$= 4.444 \times 10^{-6}\,c^2$$

$$d = 2.108 \times 10^{-3}\,c.$$

$$c = 12.5$$

$$d = 26.3 \times 10^{-3} = 0.0263 \text{ cm} = 0.011''$$

$$c = 474\,d.$$

If d = 0.016" wire. = 0.041 cm.

c = 19.4 amp. 256 mils. = 13 mils per amp.

If d = 0.020" = 0.051 cm.

c = 23.7 amp

The res: per cm. of this 0.020" (0.051 cm) wire # 25 B&S. $= \frac{84 \times 10^{-6}}{\pi\, 2.5 \times 10^{-3}}$

$$= \frac{84 \times 10^{-6}}{7.85 \times 10^{-3}} = 10.7 \times 10^{-3} = 0.0107$$

res: of 8 cm = 0.086 ω.

The res: of two such wire = 0.172 + res: of two sections 0.25 ω.

The e.m.f. in the cct = 3 volts.

the current = 12 amperes.

On the Constants (necessary) for constructing the model Milwaukee Car track. (Mr. Geyers to Prack).

(Ohms for minimum see p. 147)

The res. of a circular mil foot = 10·5 ω. say.

- - - - -	mile	= 55·440	= 5.5440×10^{-6}
- - - 390,600 × 2	- -	= 7.094×10^{-8}	= ∴ 0·0071 ω per mile
- - - 250,000 × 2	- -	= 8.09×10^{-8}	= ∴ 0·0111 ω - -
- - - 180,625 × 2		= 1.535×10^{-8}	= ∴ 0·0152 ω - -
- - - 144,000 × 2		= 1.925×10^{-8}	= ∴ 0·0193 ω - -
- - - 115,000 × 2		= 2.410×10^{-8}	= ∴ 0·0241 ω - -
- - - 56,000 × 2		= 4.94×10^{-8}	= ∴ 0·0495 ω - -

The mean effective resistance of a car absorbing 20 ampères at 562 volts = 29 ω.

The scale of the map is 500' to 1" = 1 mile to 10·56".

With 1/10th loss of the resistance, the model should operate on 6·25 volts. The res. of the 390,600 × 2 wire should be 1·1365 × 0·0071 = 0·00807 ω per ft.

- - - -	250,000 × 2	- -	× 0·0111 = 0·01262 - -
- - - -	180,625 × 2	- -	× 0·0152 = 0·01750 - -
- - - -	144,000 × 2	- -	× 0·0193 = 0·02194 - -
- - - -	115,000 × 2	- -	× 0·0241 = 0·0274 ω - -
- - - -	56,000 × 2	- -	× 0·0495 = 0·0563 ω - -

each car will be 0·28 ω in 9·3 wire.

For practical sizes, the best wire of bare copper of

model 0·00807 ω	for the 390,600 × 2 wire would be	# 19 B&S	0·00801	or # 20 B&W.	0·00843
- 0·01262 - -	250,000 × 2	- -	# 21 B&S	0·01126	# 22 B&W. 0·01317
- 0·01750 - -	180,625 × 2	- -	# 23 B&S	0·0165 ω -	
- 0·02194 ω - -	144,000 × 2	- -	# 24 B&W.	0·0202	
- 0·0274 ω - -	115,000 × 2	- -	# 26 B&S	0·02555	# 25 B&W. 0·02581
- 0·0563 ω - -	56,000 × 2	- -	# 28 B&W.	0·05266	# 27 B&S 0·05223

Data concerning an Eickemeyer Model Gramme Ring Armature examined

26th Sept. 20.

This armature (in wood) has a diameter of 12·25" (31·11 cms) over wire, and 12" (30·5) over brass. Its breadth is 3" across base 3¼" over wire and 4¼" over pegs. It is wound in 132 sections of 4 wire each or 528 wires all round. Each wire is wound in two loops over the surface of the armature being held in place by pegs projecting from the sides, 40 wires lie between the sides of the loop, so that the sides are actually 42 wires apart.

If b be the breadth of an armature, then it only pays to employ Eickemeyer winding when $(2 + \sin\frac{\theta}{2}) \times 1.5$ is $< 2b$.

that is when $\sin\frac{\theta}{2} = \frac{2}{3}\frac{b}{r}$

The ratio of $\frac{b}{r}$ in our dynamos is never greater than $\frac{1}{3}$

$$\therefore \sin\frac{\theta}{2} = \frac{4}{9} = 0.4444 = \sin 26^\circ 22'$$

$$\theta = 55^\circ$$

or 6 poles.

The winding can only be advantageous at best with centripolar and probably only with rotipolar machine.

In the Edison carbon #1 $\frac{b}{r}$ is 1·75, so it would be advantageous in this case.

On the Trial of a Sample Recording Ammeter Constructed by Messrs White & Pillington.

26th Sept: 20.

A double-conical barrel 8 cm long revolves by clockwork on a horizontal axis, in the plane of an ordinary solenoid ammeter fixed vertically above it. It bears 20 fibre plates radially projecting from its surface. These plates are cut away on one side of a line that passes spirally in one turn round the barrel. The barrel in this instrument revolves once in 6 mins.

Attached to the moving indicator arm, and partaking of its motion is a second arm pivoted on an horizontal axis at right angles to the direction of motion. The lower end of this arm is provided with a blunt stud that engages in the teeth of the barrel. The upper end carries a pawl engaging in a toothed wheel. When the stud engages with a plate it compels the toothed wheel to advance two teeth before release. The position of the ammeter arm therefore determines the number of plates that shall engage the recording arm per revolution, and hence the number of steps indicated by the train of wheel attached to the toothed wheel. In this particular model, the ammeter indicates up to 10 ampères (20 lamps) and there are 60 teeth in the escapement, and one revolution of this wheel indicates 10 on the dial, the full indication of 10 ampères then registers $\frac{10 \times 60}{60}$ in one revolution of the barrel or 6.7 or 6.67 per hour so that one amp. hr. indicated represents 6.67 on the dial, one lamp hr (one plate engaging per revolution) 3.33 per hour.

The instrument over indicated at first 9.2 amp for 7.8 about two hours later it fell to 8 ampères, (indicated).

The test commenced at 13.~~25~~ with a Standard Meter in cct. The ~~second~~ test was stopped at 9.15 on the following morning the current having been 13½ hours, and the mean indication 8 ampères = 106 amp. hr. or 700 on the dial.

The actual record was 027505 − 026830 = 675

Between 14.45 and 17.15 = 2½ hrs @ 9.0 amp = ~~22.50~~ amp. hr = 150.0 on the dial the record was 027.041 − 026.900 = 141.

An alternating current of approximately 7 ampères mean strength gave an indication of about 5 on the meter.

The res: of the instrument is 0.03 = giving a drop of 0.3 volts on full load. It has an inductance of $\frac{10.000 \times 0.1 \times 0.1}{100,000}$ = 1 kilometer, and the solenoid is composed of 66 turns in a quadrant of 1¼ layers.

The meter record was as follows.

Standard meter #1	47.863	48.0446	+ 0.183 } 0.186
	47.925	47.736	− 0.189

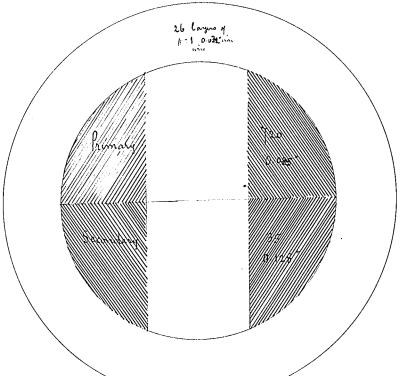
0.186 × 1000 ÷ 0.224 = 15.2 amp. hr @ 13½ = 11.47 amps.

Facts Concerning the relation between Illumination and Power in a 100 volt 16 c.p. lamp.

a 100 volt 16 m.c.p. lamp operating at 3.06 w. per c.p. takes 0.49973 amp. w. 2.0108
the same lamp at 101.02 volts takes for 17 c.p. 0.5038 " " " 2.005

The ratio of illumination is $\frac{17}{16}$ = 1.0625 the ratio of current is 1.01307

$(1.01307)^5$ = 1.0671 so that the illumination varies nearly as the fifth power of the current.



Comparison of magnetic circuits in an Edison & a Westinghouse transformer

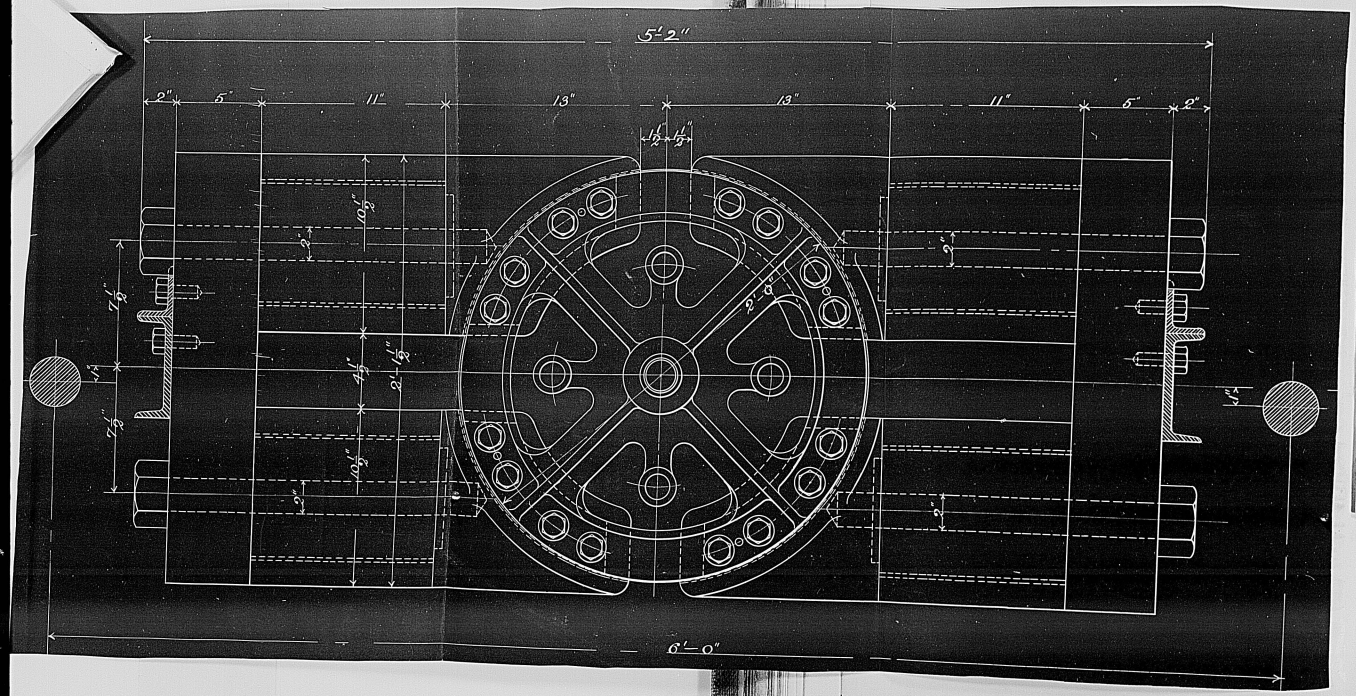
The Westinghouse transformer is already described on page 10. Edison transformer is on the same lines as that described on page 109, but with modifications in the arrangement of iron as follows:— Breadth of internal band 3·75
ext: diam. 14·3
int: " 9·95
length 20·7

720 turns on the primary in 2 lbs. 12 oz. of # 22. B+S. 0·025".
35 turns on the secondary in 3 lbs. 7 oz. of #8. B.+S. 0·128".
Total weight of 4 lbs 4 oz or 35 lbs of iron wire

With the two primaries in multiple, and the Siemens dynamo running at 107 periods per sec. 1600 revs. per min: the W. gave 44. on dynamometer with ann. antiinductive circuit while the E. gave 38, a ratio of 1·07 at 1680 revs. per min: or 112 ~ the W. gave 48, the E 39. a ratio of 1·11 so that the Edison transformer is in defect 10%.

E.M.F.	Opt. $\int_1^{(t)}$	Throw	Opt. per div.	
2 B. Cells 18°C	$2{\cdot}869 \times 10^{-7}$	139·5	$2{\cdot}057 \times 10^{-9}$	

No. of No.	Annulus	Amplitude in spring	Throws	Mean	Opt. in cent	$\frac{\Omega}{\Omega_0}$	$\frac{\phi}{\phi_0}$	Total R. in cent.			
Ext. 1	9°30'		·4	158	0	$3{\cdot}147 \times 10^{-7}$	2·368	5250			
2	16°45'		4	72	25,000	1·48		30,250			
3	52°		3	161	50,000	3·31		55,250			
4	0·200		3	84	102,000	1·73		105,250			
5	0·40		2	142	"	2·92					
6	0·79		3	213	"	4·38					
W. 1	0·80		3	198	-	$4{\cdot}07 \times 10^{-7}$		105,250			
2	0·435		3	178	-	3·66					
3	0·21		3	160	-	3·29					
4	55°5'		3	160	.	3·29					
5	160°		4	155	50,000	3·19		55,250			

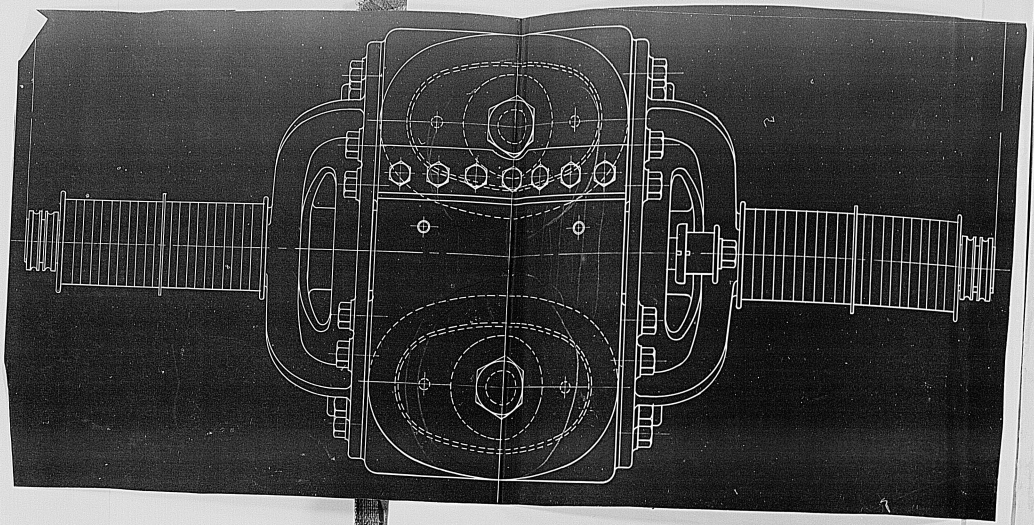


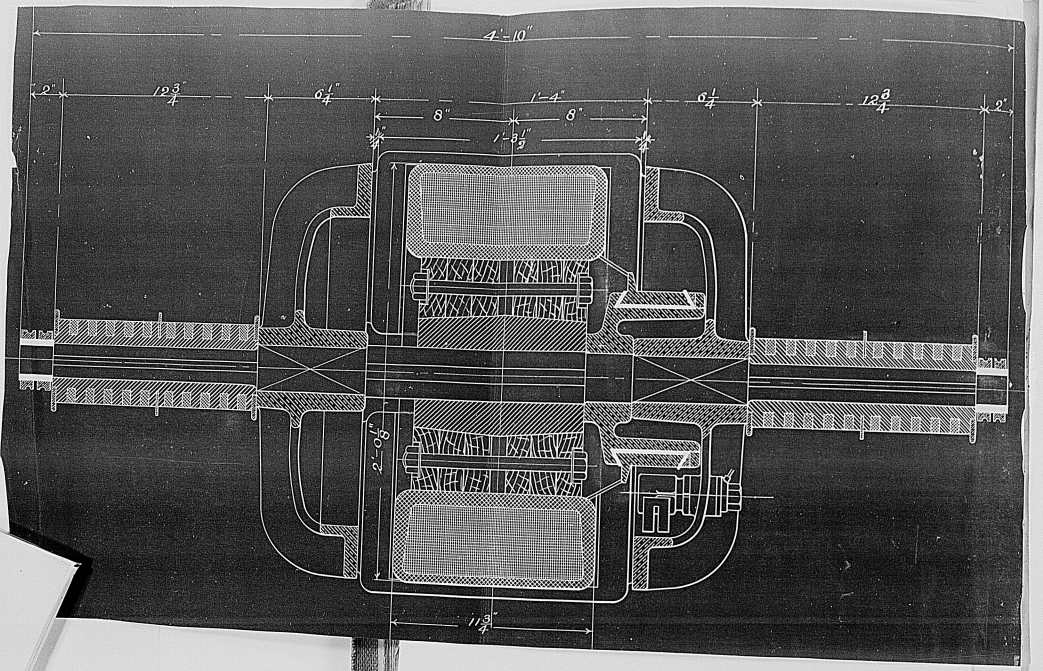
No. 2

Edison Street Car Motor

Scale 3" = one foot

Oct 7th 1890



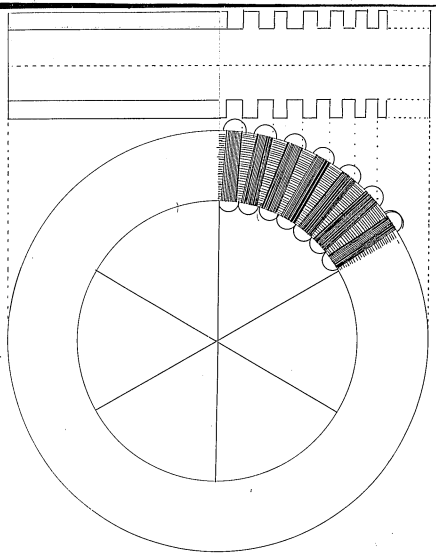


Modifications in
arrangement of

The cross section of one
By arranging the magne
it will be necessary to
This would in a
room for this, an
sufficient, so that the
outwards. Allowing
would be 10 1/2" x 10 1/2"
the core length 11" (27
sq. cms. Allowing 2 am
per Watt. It is therefo
2 amperes @ 500 volts
will be 1/2 (9.75 + 13) =
on the present motor
7500 in this instance
cient, gives 1750 turn
= 180 feet per ohm = #
at 0.913 lbs per ohm
There will be 57 x 5.5 =
of length = 28.5 sq. in
be 7/16" thick + 3/16" for
The weight of copper on
or on 4 cores 88 lbs.
The total weight of copper

Modifications introduced into the Magnetic arrangement of the No1 Experimental Motor.

The cross section of one of the field-magnet core is 215 sq. cms.
By arranging the magnets sideways, as in the Continental motor, it will be necessary to double this cross section or 430 sq. cms.
This would in a circle be 23.14 cms, but as there is no room for this, an ellipse 12" × 7" (30.5 × 17.8) is almost sufficient, so that the outline of this ellipse will be distorted outwards. Allowing for winding space, the ext: dimensions would be 15½" × 10½" (39.36 × 26.67) Taking the mean (33) and the core length 11" (27.9), the surface = 33 × 3.14 × 27.9 = 28,90 sq. cms., allowing 2 ampères at 500 volts = 250 Watts = 11.5 sq. cms per Watts. It is therefore required to find the winding for 2 ampères @ 500 volts. The mean length of one turn will be ½(9.75 + 13) = 11.4" × 3.14 = 3'. The no: of ampère turns on the present motor cores is 2500 × 2.5 = 6250. Allowing 7500 in this instance as margin of safety for longer magnetic circuit, gives 3750 turns = 11,250' of wire offering 62.5 ω hot. (= 180 feet per ohm = #19 B.W.G. 0.042". + 62.5 ω of this wire at 0.913 lbs per ohm = 57 lbs. per core + 4 cores = 228 lbs.
There will be 57 × 5.5 = 313.5 c.ins: of winding space in 11" of length = 28.5 sq. in. At 36" of circumference this would be 7/8" thick + 3/16" for copper = 1 1/16" say 1 1/4 of winding space.
The weight of copper on the iron will be 3/16" × 11" × 30.6" × 0.33 = 22 lbs or on 4 cores 88 lbs.
The total weight of copper on the field magnet will thus be 316



2) Revision of armature winding for higher electrical efficiency.

Let $w = 42 \times 4.9 = 2058$ then the diam: of cond: wire is $0.1814 \div 7 = 0.0226''$ and this with 0.010 gives 0.016 wire = #27 B.W.G.

$2058' \times 0.4 = 823.2' \times 0.044\,\omega = 32.93 \div 4 = 8.2\,\omega$ cdl.

The speed will be with this winding (running light)

$$\frac{110 \times 10^3}{1.53 \times 10^8 \times 2.06 \times 10^3} = \frac{110}{3.15} = 34.9 = 2100 \text{ per min.}$$

3) Let $w = 42 \times 6.4 = 2688$ then the diam: of cond wire is $0.1814 \div 8 = 0.0227$ and conductor 0.013 = # 29 B.W.G.

$2688' \times 0.4 = 1075' \times 0.064 = 71.7 \div 4 = 18\,\omega$ cdl.

The speed with this winding will be (running light)

$$\frac{110 \times 10^3}{1.53 \times 2.69 \times 10^3} = 26.7 = 1600 \text{ per min.}$$

On completion 21st Oct. res: of armature 7.15 @ 20°C.

Weight of armature body + spider	5. 15¾ cq
" " " winding	15 cq
" " " complete	4 11 3
Total Weight of machine - without base or pulley	27 lbs. (nett)

Diam: of field core 4.75 or 1.875" Area 17.8 sq. ins. B = 18,500

Electromagnetic Design for a small Edison Motor of new type, bipolar gramme-ring, with pacinotti teeth. (132)

Power 150 Watts: To operate between 100 + 125 volts at mt. Taking 125 volts as normal in what follows:-

Speed 2500' per min: at periphery = 1250 lines. (15.9 ins. = 26.5 per sec)

Dimensions of armature. Iron body

External diam: 6" (15.2) External diam: 4¼" (10.2)

Breadth: between 18.85 (47.9) edges of grooves 1" (2.54) (32.05)

Entrefer 3/64" on each side (0.119)

42 grooves ℄ apertures. Walls of grooves parallel.

Winding calculation.

The cross section of iron is $6.45 \times 2 = 12.9$ sq. ins. and the density permissable 12,000 = 152,800 = φ.

$\varphi w = 125 \times 10^8 \quad \therefore w = \frac{125 \times 10^8}{1.53 \times 10^8 \times 26.5} = 3.08 \times 10^2$

$w = 3080$ in all

in each groove 73.4. The nearest square to this is 81. $\frac{18.85}{84} = 0.224$ = breadth and depth of groove. allowing 0.020" for body insulation leaves 0.184 for wiring breadth = 0.0205 for diam of 1 wire in 9 turns 0.011" wire # 29 B.S. d.c.c. allowing 0.009" for covering = 127 cmil = 254 cmil total capacity = 1.27 amp. at 200 cmil per amp. = 127 to 156 Watts according to voltage.

Magnetic circuit.

The surface presented by a single tooth is $\frac{0.224 + 0.171}{2} \times 0.150$ = 0.97 sq. ins. Supposing the covered on each side gives 28 sq. ins. The reluctance of this will be

$\frac{0.119}{28}$ at each polar surface =	0.00425
	0.00425
Identity ins. of polar extension × section 12	0.003
1B ins. of armature section 6 ÷ 2	0.0085
Total	0.013 Rects.

Flux needed is 152,800 allowing for leakage and any discrepancies 305,600 ∴ MMF = $305.6 \times 10^5 \times 1.3 \times 10^{-2} = 3.97 \times 10^3$ = 3160 A.T.

Allowing ½ amp. the res: of the field coil will be 1000 ω and there will be 31,600 turns. The mean turn will be $\frac{1.85 \div 3}{2\pi} \pi = 0.616' \times 31,600 = 20,060'$ for 1000 ω = 20 ft per ω = # 28 B.W.G. @ 0.0113 lbs per ω = 1143 lbs. in all. 0.014" when covered = 0.019" and 0.020 As this occupies too much space, take the entrefer as 1/32" on each side. This will reduce the reluctance to 0.01 Rects. the MMF 6.3×10^3 = 1600 A.T. = 16,000 turns of ½ amp = 1000 ω. The mean turn being 0.616 feet the 16,000 ω, 10,240' for 1000 ω = 10.24 ft per ω. # 31 B.W.G. 0.010" = 2.93 lbs in all. or # 30 B.S. 0.010" 2.96 lbs. in all.

The mean turn on the armature is 0.4' and there are 3080 turns = 1232' of # 29 B.S. @ 8.1×10^{-3} ω per ft = 100 ω ÷ 4 = 25 res. of armature. = 3.04×10^{-4} lbs there will be 4.73×10^{-1} lbs. ½ lb.

If an insulation of 0.005" were allowed for this wire on the armature the diam of copper would be increased from 0.011 to 0.015" and the capacity of the machine doubled.

Measurement of the mean thickness of a coating of rust on a mass of iron wire.

1st October. Microscopic measurement. 0·01" stage micrometer = 3·00 mm.

1st sample	rusted diameter	28·93 mm = 0·0320	cleaned diam.	27·93 mm = 0·0310
2nd	-	28·40 = 0·0316	"	27·55 = 0·0304
3rd	-	27·93 = 0·0310	"	28·05 = 0·0316
4th	-	28·85 = 0·0321	"	28·09 = 0·0311
5th	-	29·10 = 0·0323	"	28·10 = 0·0312
	Sums	143·11 = 0·1590	"	139·43 = 0·15553
	Means	28·62 = 0·0318	"	27·886 = 0·03106

Mean Difference = 0·00074

- Thickness = 0·00037

On the Cost of Power necessary to keep a Large Vessel's Hull clear of weed and rust by electrolysis.

A large vessel 800 feet long and drawing 30 feet would probably expose 370,000 square feet maximum surface. Allowing 1 ampère per sq. foot and 7 volts = 490,000 Watts say 500 kwts. @ $15 per ann. = $7500 annually.
One amp. hr. dissolves 0·7 grms iron. and 370,000 = 49,000 grms hourly = 108 lbs or 2540 lbs daily = 1·27 tons = 460 tons yearly @ $30 per ton = $13,800. Total cost $17,500 excluding labor and interest on plant.

On the Resistances needed for Feeder Equalisers at Ogden Mill

The normal current in the 6 machines is 30 ampères at 120 volt = 3·67 ω all told, and it is desired to have a box in circuit with each such that at 120 or 125 volts the current can be varied from 25 to 35 ampères.

At 120 volts	25 amps	means	5·2 ω	
" 110 "	35 "	"	3·14 ω	
		Difference	2·0.	

In 36 resistances of 0·33 ω each = 0·05 ω in multiple

To break the circuit of any one machine a resist. box will be needed from 0. to 50 ohms. in following steps

	0·1	0·2	0·3	0·5	0·7	1·0	1·5	2·0	3·0	5·0	10·0	20·0	50·0
Individual step	0·1	0·1	0·1	0·2	0·2	0·3	0·5	0·5	1·0	2·0	5·0	10·0	30·0
To carry	35	"	"	"	"	"	20	"	"	15	10	"	5

6 Feeder equalizers and 2 Breaking boxes will be needed.

Basis of Determination.

113 Electromotors each pulling one trailer.
Double track everywhere except on Chambers St. 1700 ft.
Edison Motors. Double trolley wires
20% drop maximum. No feeder.
Minimum p.d. in main 500 volts. Maximum at Station 625.

Weight of Electromotor & trailer loaded 15 tons.
@ 20 lbs per ton = 300 lbs, 5 miles per hr. = 3600 ft lbs per sec.
= 6.5 H. mechanical = 10 ampères @ 500 volts = 20 ampères @ 50% η

Basis of model.
Single track with all cars on it and double conductivity.
All resistances are 1/10 times as great per mile on the model as the actual. Mean P.D. 562 volts 20 amp = 28w
Car model are all 2.8w each.

Resumé of Conductors

Diameter Inches	B.M.E.	Wt: per foot. lbs	Length Wire feet	Total Wt lbs.	Cost @ $0.28 per lb
0.625"		390,600	1.204	294,200	354,200	88,540
~~.5~~"		250,000	0.77	66,000	50,820	12,710
0.425	000	180,625	0.5563	189,940	105,700	26,430
0.380	00	144,400	0.4448	29,760	13,240	3,310
0.34	0	115,600	0.35	25,000	8,750	2,190
0.238	4	56,640	0.1715	22,860	3,920	960
				627,760	536,630	134,140

STREET RAILROAD DATA.

Abstracts from a thesis by L.W.Healey, and J.W.Cowles gradu
of Cornell, written May 1890. From tests made on the system
at Scranton Pa. Partly worked with Sprague, and partly with
T . H . cars. Running since 1886K. Station 2 miles from cen
of city beside a culm-heap which is used with special grates
for fuel at ten cents per ton. The plant has five horizonta
tubular boilers rated at 125HP each, 3 A&S engines 260 revs
15 1/2 x 15" driving each a pair of Edison 500 volt,100 amp
dynamos by direct belting. 30 cars each fitted with 2-15HP
motors. the system is the single overhead trolley wirewith
seven feeders, and rather hilly district.There is mention of
a ground conductor.Cars run from 4.30 to 24 oclock daily.
Water from city mains. Electrical readings during test taken
every fifteen mins. Grade tests made with a special car.
Weight of this car not given and no mention made of weight o
any cars. Power tests made by Prony brake on one motor, jack
Average boiler press 88.45lbs. Temp. 246°f duration of test
20 hours.Average quality of steam 97.15%.Water evaporated pe
lb. of combustible from and at 212° 9.11lbs.Average comm.HP of
boilers 278.Avr. Friction card of #1 engine dynamo open cct
12.6,ditto #2,#3 10.2

Max. I.H.P.	411.9	Max. EHP	314.2
Min. I.H.P.	10.28	Min E.H P.	5.16
Avr. IHP	257.7	Avr. EHP.	196.7

Avr. comm eff.of dynamos ~~G=28~~ 92, and of system0.76 down t
feeder K..34.5 lbs. of water per IHP per hour or 44.86lbs. pe
EHP 4.08 lbscombustible per IHP per houror 5.34 lbs. combus
ible per EHR per hour. 30 cars Total car milage 7069
Passengers 10,150 Avr IHP per car 8.59 Avr. EHP 6.56:295 lbs
of water per car hour, 35 lbs of combustible or 56.2 lbs. of
culm per car hour. PD. on car varied from 406 to as low as
298 in few cases. Highest grade 9.75%, absorbing 82 amp. at
408 voltsboth Sp, and TH. Speed on level 13.6 m.p.hr. TH wi
24.6 amp: at 367 volts or 12.1EHP and 17 m p hr. with Sp.
17.0 amp at 390 volts or 8.9EHP. Avr. Insulation of system
by Wh.br. 764 ohms. Ratio of TH gearing 9.41 of Sp. 11.7
The brake eff. of the TH. is 37% at 12.8 m p hr. with 1.74
BHP. up to 85% at 8.3 m p hr. at 8.85 BHP. The Sp. eff. was
56% eff. at 13.6 m p hr. 2.0BHPup to 90% eff. at 6.6 m p hr.
and 7.1 BHP.

Abstracts from the report of a test made by Mr. C. F. Hamilton, on the effect of introducing the equalizer field coil to the Sprague Car, in Scranton Pa. 1st. Oct. 90

A car was operated with a light load four times along the same section, and the currents in the two motors measured at the same instants and at regular intervals of time, using two ammeters. The pressure averaged 375 volts on the car, and the road was rough and grades steep. A large number of readings were taken but the general means only are here given.

Up run. Motor A 11 amperes Motor B 17.5 amperes.
Down run 14 12

This was without equalizers, and words up & down refer only to direction. The rear motor on a grade is stated to take the greater current.

Oct. 2nd. Car 3 without equalizer. Level road and even load
Down run Motor A 22 amperes. Motor B. minus 11 amperes.
Up run 18 minus 1.7
Motor A run alone, B cut out of circuit.
Up run A 15 amperes. Down run A 8 amperes
Motor B run alone, A cut out of circuit.
Up run Motor B 14 amperes, Down run Motor B 9 amperes.
The opposition of the two motors took place on and after the 3rd. notch of the switch.

Same car Oct. 4th. equalizer in place but not yet in circuit.
Up run Motor A 20.8 amperes. Motor B 0 amperes.
Down run 15.5 minus 1.4
Equalizer next employed, no other change.
Up run Motor A 16.9 amperes. Motor B 3.5 amperes.
Down 12.7 2.3
Oct. 8th. Car #2 First without equalizer
Up run Motor A. 17.5 amperes. Motor B. 7.9 amperes.
Down 17. 6.8
Equalizer applied, no other change.
Up run Motor A 12.9 amperes. Motor B. 9.4 amperes.
Down 11.2 5.7

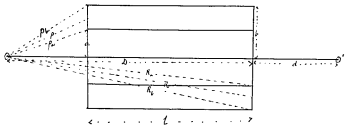
The general mean of all results indicates that the average current taken by the car was 23 amperes without equalizer, and 19.6 amperes with it.

Extracts from a memorandum by Mr. J. H. Vail on Milwaukee

Estimated weight of car and trailer is:- 16 ft. car 60001bs Truck 2000, Motor and fittings 5000, 60 passengers 8400 and trailer 16000 making a total of 37, 400 lbs. or 18.7 tons. Cars are expected to make 10,-12,-14,-and even up to 20 miles per hour. 10 or 12 miles not unusual when car leaves center of city. Estimates current per car 35-40 amperes. Double trolley wire system very expensive. . Only present paying lines in States use single trolley. Under existing practise the trolley wires are supplied from the subfeeders every 400 feet.

On the Determination of a Conducting Trolley Wire System for Milwaukee Wis.

No.	Street	Track Length	Track feet	Trolley feet	Grade	Motor R. feet	C. Mile	Motor R. per	Total W.	Max No. Car	Feet	Total cost
									lbs.			$
1	Center	5.88	2,940	11,760	0.025	0.01657	180,625	0.171	6,540	1	16	1,640
2	Wright	9.25	4,620	18,500	0.025	"	"	"	10,280	2	13.5	2,370
3	Walnut	16.75	8,380	33,520	0.025	"	"	"	18,650	5	13.5 9	4,660
4	Chestnut	14.88	7,440	29,760	0.022	0.0213	144,400	0.215	13,240	6	12.5 8.5	3,310
5	Third	3.3	1,650	6,600	0.014	0.05267	56,600	0.548	1,132	1	15	280
6	Eighth	20.0	10,000	40,000	0.025	0.0132	250,000	0.126	39,800	6	15 11.2	7,700
7	Third	13.75	6,880	27,500	0.025	0.01657	180,625	0.171	15,300	4	11	3,820
8	"	6.0	3,000	12,000	0.028	0.0132	250,000	0.126	9,240	2		2,310
9	Richards	10.0	5,000	20,000	0.025	0.01657	180,625	0.171	11,130	3	9.15	2,780
10	Murray	19.75	9,880	39,500	0.025	0.01657	180,625	0.171	21,970	1	11 16	5,490
11	Racine	1.5	750	3,000	0.014	0.05267	56,600	0.548	514	1	9.15	120
12	Brady	13.5	6,750	27,000	0.025	0.01657	180,625	0.171	15,010	4		3,750
13	Dock	1.88	940	3,760	0.025	0.01657	180,625	0.171	2,090	2		520
14	State Market	7.0	3,500	14,000	0.028	0.0132	250,000	0.126	10,780	1		2,700
15	Broadway	4.6	2,300	9,200	0.035	0.00843	390,600	0.0807	11,070	3		2,770
16	Kinnickinnic	36.25	18,120	72,500	0.035	0.00843	390,600	0.0807	87,200	14	21	21,830
17	Mason	2.5	1,250	5,000	0.025	0.01657	180,625	0.171	2,780	1		700
18	Michigan	3.25	1,630	6,500	0.014	0.05267	56,600	0.548	1,120	2		280
19	Clybourn	1.88	940	3,760	0.014	0.05267	56,600	0.548	645	2		160
20	Huron	1.75	880	3,500	0.035	0.00843	390,600	0.0807	4,215	2		1,050
21	Sycamore	1.5	750	3,000	0.014	0.05267	56,600	0.548	514	-		130
22	Reed	17.25	8,630	34,500	0.035	0.00843	390,600	0.0807	41,500	10		10,380
23	National Ave.	35.25	17,630	70,500	0.035	0.00843	390,600	0.0807	84,900	8	20 17.5	21,220
24	Washington	9.0	4,500	18,000	0.035	0.00843	390,600	0.0807	21,680	2		5,420
25	Greenfield (W)	6.75	3,380	13,500	0.020	0.0258	115,600	0.268	4,725	2	12.5	1,180
26	" (E)	9.0	4,500	18,000	0.035	0.00843	390,600	0.0807	21,670	4		5,420
27	11th Muskego	14.0	7,000	28,000	0.035	0.00843	390,600	0.0807	33,700	3	14	8,430
28	Forest Mitchell	17.0	8,500	34,000	0.035	0.00843	390,600	0.0807	40,930	4		10,230
29	Windlake	3.0	1,500	6,000	0.035	0.00843	390,600	0.0807	7,220	1		1,800
30	"	5.75	2,880	11,500	0.020	0.0258	115,600	0.0807	4,025	2		1,010
31	Chamber	3.4	1,700	3,400	0.025	0.01657	180,625	0.171	1,890	-		470
		315.57	157,820	627,760					536,560	101		134,140



Mathematical Determination of the Difference of Electromagnetic Potential between two points on the axis of a uniform and homogeneous compound solenoid situated outside its terminal planes and equally distant in opposite directions from its centre of figure. (13)

Let ρ be the current per unit area of longitudinal section (abcd). Then the potential at O of an elementary ring $dr\,da$ of radius r and dist. a

$$dV = 2\pi\rho\, da\, dr\left(1 - \frac{a}{\sqrt{a^2+r^2}}\right) \qquad (1)$$

Consider any cylinder of radius r, and integrate from $a = d$ to $a = D$

then
$$\frac{dV}{2\rho\pi dr} = \int_d^D da - \int_d^D \frac{a\,da}{\sqrt{a^2+r^2}} \qquad (2)$$

$$= (D-d) - \sqrt{D^2+r^2} + \sqrt{d^2+r^2} \qquad (3)$$

$$\therefore \frac{dV}{2\pi\rho} = l\,dr - dr\sqrt{D^2+r^2} + dr\sqrt{d^2+r^2} \qquad (4)$$

Integrate this from $r = a$ to $r = b$.

$$\frac{V}{2\pi\rho} = \int_a^b l\,dr - \int_a^b \sqrt{D^2+r^2} + \int_a^b \sqrt{d^2+r^2} \qquad (5)$$

$$= l(b-a) - \left[\frac{r}{2}\sqrt{D^2+r^2} + \frac{D^2}{2}\log\left(r+\sqrt{D^2+r^2}\right)\right]_a^b$$
$$+ \left[\frac{r}{2}\sqrt{d^2+r^2} + \frac{d^2}{2}\log\left(r+\sqrt{d^2+r^2}\right)\right]_a^b \qquad (6)$$

Abbreviating as in figure
$$\frac{V}{\pi\rho} = 2l(b-a) - \left\{b R_b + D^2\log_e(b+R_b) - a R_a - D^2\log_e(a+R_a)\right\}$$
$$+ \left\{b\rho_b + d^2\log_e(b+\rho_b) - a\rho_a - d^2\log_e(a+\rho_a)\right\} \ldots \qquad (7)$$

The potential of the coil at O′ must be numerically equal to this with the opposite sign, increased by $4\pi\rho(b-a)$

$$\therefore \frac{V'}{\pi\rho} = +2l(b-a) + \left\{b R_b + D^2\log_e(b+R_b) - a R_a - D^2\log_e(a+R_a)\right\}$$
$$- \left\{b\rho_b + d^2\log_e(b+\rho_b) - a\rho_a - d^2\log_e(a+\rho_a)\right\} \qquad (8)$$

$$\therefore \frac{V'-V}{2\pi\rho} = b(R_b-\rho_b) - a(R_a-\rho_a) + D^2\log_e\left(\frac{b+R_b}{a+R_a}\right) - d^2\log_e\left(\frac{b+\rho_b}{a+\rho_a}\right) \qquad (9)$$

For a lesser degree of accuracy, let $R^2 = D^2 + \left(\frac{a+b}{2}\right)^2$ $\rho^2 = d^2 + \left(\frac{a+b}{2}\right)^2$

Then $V'-V = 4\pi\rho(R-\rho)$, or if Γ be the current in the Rolls
N = total no. of turns

$$V'-V = 4\pi\Gamma N\left\{1 - \frac{l-(R-\rho)}{l}\right\} \qquad (11)$$

$$\text{or} \quad = 4\pi\Gamma N\left\{\frac{R-\rho}{l}\right\} \qquad (12)$$

As an instance, take the following case

$l = 20$, $d = 5$, $D = 25$, $a = 2$, $b = 4$, $\Gamma = 1$, $N = 4{,}000$

$\therefore R = 25.18$, $\rho = 5.8$, $R_b = 25.32$, $\rho_b = 6.44$, $R_a = 25.08$, $\rho_a = 5.39$

The ordinary formula gives $(4\pi\Gamma N)$ $V'-V = 50{,}280$

" (12) " 48,730

" (9) " 48,700

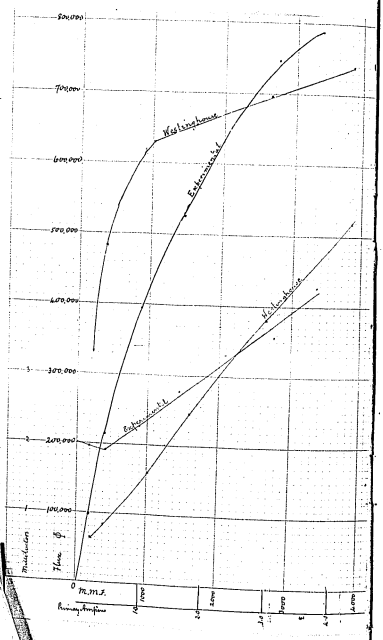
If the points are not equidistant from the midplane along the axis let d_1 and d_2 be their distances from the terminal planes respectively.

$$\frac{V'-V}{\pi\rho} = b(R_{1b}+R_{2b}-\rho_{1b}-\rho_{2b}) - a(R_{1a}+R_{2a}-\rho_{1a}-\rho_{2a})$$
$$+ D^2\log_e\left(\frac{b+R_{1b}}{a+R_{1a}}\right) + D^2\log_e\left(\frac{b+R_{2b}}{a+R_{2b}}\right)$$
$$- d_1^2\log_e\left(\frac{b+\rho_{1b}}{a+\rho_{1a}}\right) - d_2^2\log_e\left(\frac{b+\rho_{2b}}{a+\rho_{2b}}\right) \qquad 13.$$

0·1981	0·1999	0·0018	1	~~0·0018~~ $\times 10^{-6}$	3·24
	0·1988	0·0007	2	~~0·0014~~ 49	0·98
	0·1975	0·0006	4	~~0·0010~~ 36	1·44
	0·1976	0·0005	2	0·25	0·50
					$6.16 \times 10^{-6} \sqrt{} = 2\cdot$

$0.3894 \times 2.482 \times 10^{-3} = 0.967 \times 10^{-3} \div \sqrt{g} = 0.32 \times 10^{-3}$

0.0003



Obach Galvanometer Constant

Simple Ring (1st October 90. (Tragar ch)

(136)

Determination with the aid of a silver voltameter in 3 trials and - - -

Test of Street Car low volt motor running as a dynamo. 9th Oct. 90 See p. 60 + 17 Book II.

920 revs: 12 volts p.d. subsequently 950 revs: 7.7 volts 3.6 amp. in field. The armature bolts of the machine were subsequently found to be broken and to renew them would necessitate disconnecting the commutator. The machine was consequently discarded.

Test of Alternating & Continuous current Machine

Speed 1470 revs: 5.3 amp. through field. Bender defln 136° equivalent to volts with continuous current.

Test of the three Standard Meters.

The three meters were connected in series, and a current of 10 amp. passed through them for about 40 hours.
The resistance of these meter circuits are:-

Number		Res. of Shunt Light Ohms	Temp.	Res. of Arm'd Light Ohms	Temp.	Ratio Arm'd to Shunt	Mpgs. transfer for amp.	Transf. Res. per megger transfer
Book II p. 152	1	0.0993	23°C.	98.05	21°C.	1017.6	1.2028	0.8344
"	2	0.09945	22°C	98.03	22°C.	1015.9	1.2048	0.8300
Book I p. 47	3	0.37614	23.3°C	514.3	19°C.	1374.3	0.8906	1.1228

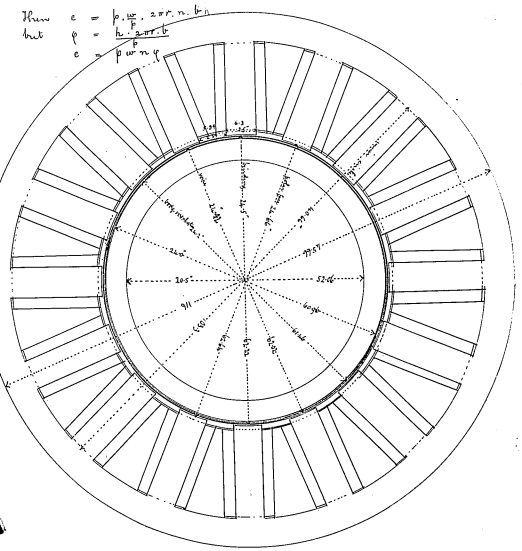
No. of plate	Weight before test	Weight after test	Gain	Loss	Complete gain	Accepted transfer	Amp. hrs.	Mean
Meter 1 3	49.316	48.842		0.474	0.025	0.487	404.9	
4	50.169	50.669	0.500					
" 2 5	49.952	50.456	0.504	1	0.022	0.488	405.0	405.4
6	49.396	48.914		0.472				
" 3 7	50.465	50.107	0.	0.358	0.008	0.362	406.4	
8	49.781	50.147	0.366					

Let b be the breadth of armature
" w " " no. of wires all round
" p " " " poles and segments
" h " " mean field
" r " " radius
" n " " no. of revs. per sec.
" e " " emf.

Then $e = p \cdot w \cdot 2\pi r \cdot n \cdot b \cdot h$

but $p = \frac{h \cdot 2\pi r \cdot b}{\phi}$

$e = \phi \cdot w \cdot n \cdot p$



Edison Experimental Alternator 700 lamps Section at right angles to axis

Scale 1/6

PARTICULARS OF EDISON EXPERIMENTAL ALTERNATOR NO. ONE.

Gramme Ring armature, and 16 poles.

Power. 60 Kilowatts. 50 amperes mean current at 1200 volts mean EMF. or of sufficient capacity to operate 700 lamps of 50 watts each at an intermediate loss of 30 %.

Speed. 1200 revs. per min. or 20 per second. peripheral speed 7700 feet per min. or 128 feet per second.

Frequency. 16 alternations or 8 per rev. , 160~ per second 9600~ per minute, or 19,200 reversals.

Dimensions.	Diam. of armature body. internally	20.5"
	externally	24 "
	over insulation	24.2"
	over conductor,	24.42"
	over binding	24.5"
	Diam. of polar face circle	24.67"
	field frame internally	40.67
	externally.	45.67
	Diam. of iron wire recommended for arm.	0.032"
	Breadth of armature	10. "
	Clearance	0.084"
	Entrefer	0.33"
	Width of poles	2.5"
	Breadth of poles	10. "
	Thickness of pole plates	0.125"
	Distance between adjacent polar ends	2.33"
	Number of plates composing fields	640
	Weight of iron in magnets	1620 lbs.
	Weight of iron in armature	2951bs.

Armature. Body insulation of 0.1" all round.
Winding 512 turns of No. 18 AWG. 0.095" dcc. to 0.110" in one layer of 16 segments. , segments being reversed in succession. The two adjacent ends to be carefully separated and insulated.
Max. EMF. per segment 150 volts. or 2400 volts in all
mean EMF. 1530 at full load. Area of wire 9025 c mn giving 180 c mils per amp. mean, and 163 c mils per amp. effective, at full load.

Weight of conductor	28 lbs.
Length of conductor	1025'
Resistance of conductor hot	1.3 ohms.

Field. Magnetic Circuit.

Flux through poles estimated	2,000,000
Leakage estimated	500,000
Induction density in magnets	12,400
in armature iron	9,300
in armature space.	6,650
allowing space factor of 0.7	0.017 lucts
Estimated reluctance of circuit,	

Magneto-motive Force estimated to be needed	12,800
Ampere-turns	10,180
on each core,	5,090
Current in field magnets	18.67amp.
Number of turns on each core,	273
Surface of spool	1400sq. cms.
Energy per sq. cm.	0.01 Watt.
Field winding 34 lbs. of # 10 AWG. 0.134" sec. or 630 ' in 273 turns on each core of six or perhaps seven layers.	
Total depth of winding above iron	1.0"
Resistance per core cold	0.35 ohm
hot	0.4ohm.
Total res. of fields in series hot	6.4 "
P.D. maintained by exciter on field	120 volts.
Standard Size of Edison dynamo exciter #1.	

Power absorbed in field magnets full load 2240 W.
Power absorbed by exciter in maintaining 2040
Power absorbed in mechanical friction 2000
Hysteresis estimate 2560
Foucault estimate in field and arm. 440
Power lost in armature resist. full load 2800
Power estimated for running light 7000
" " " " full load 11,480
Power estimated for at full load 60,000
Total estimated commercial efficiency of dynamo and exciter at full load. 84 %

On the outlines of a design for a 600 light Alternator with a frequency of 125 ~ per sec, 6500 ft. per min. peripheral velocity, and 30" ext: ann: diam.

With 8 poles there will be 4 periods per revolution, and consequently there must be 31.25 revs: per sec: ~~or 65~~ 1875 revs: per min: @ 6500' per min = 3.28' per circum: = 12" diam.

Taking 20 poles, and 30" circumference, for 160 ~ per sec. there must be 16 revs: per sec, or 960 per min, and 2.5' diam. = 7.85' circum: = 7.540' per min: 94.2" circum = 4.7" per magnet & clearance.

The e.m.f. to be generated must be 1500 volts allowing for inductance. At the top of the curve if it be sinusoidal the emf must be 1.6 × 1500 = 2400 volts, or 120 volts per segment.

So that
$$120 \times 10^8 = \varphi \times 16 \times w$$
$$\varphi w = 7.5 \times 10^8$$

With 16 radial poles, there will be 1200 revs: per min: or 20 per sec. for 160 ~. The ext: diameter being 24", the circumference will be 6.28' = 75.4". Allowing for a total e.m.f. of 2400 volts, each segment will be generating 150 volts, so that
$$\varphi w = 1.5 \times 10^{10}$$

Suppose 10% of the available exterior armature surface taken up for insulation purposes, the diameter of the interior will be say 20" circ: 62.8" − 6.3 = 56.5. The current carried by the machine will be about 444 amp: at full load, or 88,000 cmil @ 200 per amp. = # 13 B.W.G. 0.095" bare = 0.110" covered. There will be room for 582 turns of this wire or 328 per segment.

$$\therefore \varphi = 1.5 \times 10^6$$

Allow a density of 6500 in the armature space = 230 sq. cm or half of this on each side = 115 sq. cms: of cross section. With a depth of 1.75" (4.45) the breadth = 25.8 or 10".

Allowing a density of 15,000 in the iron there must be 150 sq. cms in the polar projections. The polar face circumference being 77.46", the face of each pole allowing an equality of pitch is 2.42" = 6.15 cm × 25 = 150 sq cms.

The embrifer is as follows:— Body) insulation 0.1" Wire 0.11", binding wire 0.034", Clearance 0.05" Total 0.33" = 0.85 cm.

The reluctance is $1.7 \div \frac{200}{2} = 0.017$ unit, and the m.m.f. required to drive $\frac{1.5 \times 10^6}{2}$ lines through the circuit will be 1.275×10^4 A.T. or 5,975 A.T. on each spool. The spool surface is = 10,450 20 × (25) × 2 = 11,000 sq. cm, and allowing 20 Watts per sq. cm. gives 70 Watts per spool, the e.m.f. on each spool will be $\frac{120}{16} = 7.5$ volts or 9.3 amp. = 644.0 turns. The length of each turn will be approximately 2.3 ft. so that the total length will be 1470', the res: of which must be 0.806 ω. say 0.7 ohm = 2100' per ohm. = # 9 B.W.G. and 1470' @ 0.066 lbs. per ft. = 97 lbs.

Allowing 0.010 Watts per sq. cm, from the spool surface gives 110 W. 18.67 amp. = $\frac{5000}{18.67}$ = 273.0 turns × 2.3 ft = 628 ft. offering 0.86 = 1800 ft per ω = # 10 B.W.G. + 628' × 0.0584 = 34 lbs × 16 = 544 lbs in all.

The diam: of this wire is 0.134 = 19,000 cmil = 950 cmil per amp.
" " " covered - 0.150 dia 7.7" = 50 wire in each layer, and 5.5 layers deep = 0.73" of wire say 0.9" in all.

45.7 inch = 1640
40.7 " = 1301
339 sq. in.

5 × 339 = 1695 cubic in.
+ 16 × 8 × 10.255 = 3200 " "
+ 2.558 × 2.506 = 500 " "
5400 " " @ 0.30 = 1620 lbs.

24.0" area 452.4
20.5 330.1
122.3 sq. in.

10 × 0.8 × 8.2 ×
= 978.4

Field winding revision.

To send 750,000 lines through the magnetic circuit, a MMF. of 15,100 will be needed, this allowing for a reluctance of 0.017 in the air space, and 18% above 0.03 in the armature.
A.T. 12,022 or 6,011 on each core = 322 turns × 18.67 amp.
322 turns @ 2.3' mean turn = 740' of wire offering 0.35 ω cold
= 2114' per core = # 9 B.W.G. 0.148
award 0.160

In 7.5" there will be 45 turns and in all 7 layers, occupying 1.17" or with spool say 1.3" = depth.
740' @ 0.0663 lbs. per ft = 49 lbs or 784 lbs. on all cores.

Particulars of Edison Experimental Alternator.

Power: 60 Kilowatts 50 amp. mean current @ 1200 volt mean emf.
16 poles, gramme ring armature.

Speed 1200 revs. per min, 20 per sec. = 7700 ft per min:
or 128 ft. per sec. at periphery.

Frequency 16 alternations or 8 ~ per revolution. = 160 ~ per second 9600 ~ per min or 19,200 reversals.

Dimensions

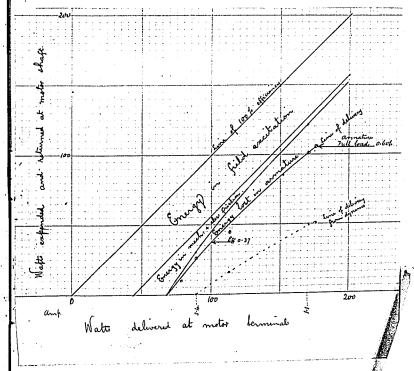
Diameter of armature body	20.5" int:		1½" drop (pressed from wire)
" " "	24" ext.		
" " " new insulation	24.2"		
" " " wire	24.42		
" " " binding	24.5		
Breadth of armature	10."		Clearance 0.08 1/16"
Diameter of iron wire # 21 B.W.G.	0.032"		
" " polar faces	24.75"		
" " inner surface frame	40.75"		
" " outer " "	45.75".		
Width of polar heads	2¾"		
Distance between polar ~~extremities~~	2¾"		
Breadth of poles	10".		
Sheet thickness of wrought iron	⅛".	150 sheets, each way.	
Volume of iron in field	5400 c.i.	1620 lb. mass	
" " " armature	978.4	294 "	
Number of plates in field	640.		

Armature. Body insulation of 0.1" all round. Extra good.
Winding one # 13 B.W.G. 0.095" d.c.c. to 0.110" 5.12 turns round in 16 segments of 32 wire each, these segments to be reversed in succession. The two ends to be very carefully separated and insulated. Maximum emf. per segment = 150 volts = 2400 volts in armature, mean emf. 1520 volts.
Area of wire 9,025 c.mil. mean area/pressure 180 at full load mean area per effective ampere 163 cmil. - - -

Fields. Mean Induction in armature space 6,650 = 9200 in iron. allowing 0.9 as net factor and 0.785 as space factor = 0.707
Cross section of armature 17.5 sq. in. = 113 sq. cm. = 750,000 ω flux
Polar flux 1,500,000 and polar cross section 2.5 × 10 = 25 sq in
= 161.3 sq. cm. induction, allowing 25% for leakage = 2,000,000/12.4 = 12,400 in iron. Field winding 273 turns of no 10. B.W.G. 0.134" in six layers of 45 turns each. Total resistance of wire 0.35 ω cold = 33 lbs. total length 273 × 2.3 = 628' × 0.052 ω = 33.9 lbs. say 34 lbs. Surface of spool only 1400 sq. cm. all spools in series = 0.24 × 16 = 6.2 ω and current 18.67 amp. needing 119.5 volts. Energy in each spool 18.67 × 119.5/16 = 140 = 10 sq. cm. per Watt. Total energy absorbed in field 2240 Watt supplied by a #1 Edison dynamo. M.M.F. of field magnet = 18.67 × 273 × 1.257 × 2 = 12,820 and the reluctance is only the entire and 10% for iron wire above this = 0.33 × 2.54 × 2/600 = 0.017 but ~~taken~~ overshot = 750,000 lines.

Armature wire. One turn = 2' = 1024 feet in all = 1.3 Ohm hot 28 lbs. wire
fall of potential mean 65 volts, effective 71 volts.
loss of energy) frictional in armature at mean full load 3200 Watts, at effective full load 3740 Watts.
Total loss of energy in resistance at full load fields and armature 6000 Watts add friction, ~~and~~ foucaults.
Hysteresis, 160 × 10,000 × 16,000 = 256,000,000,000 = 2560 Watts.
With foucaults say 3000 Watts. Friction 2800 Watts
88% Machine will absorb 8740 Watts at full load generating 60,000
" " " 7240 " " no load " 0

No	Energy in dynamo	Remarks
1	–	Current through field magnets. (145 Watts)
2	–	Motor armature uncoupled and running light (70 Watts or 30 in friction) torque 93 grms
3	–	Motor armature driving dynamo armature in unexcited field. 33.9 Watts 168 delivered
4	–	- - - - - and excitation.
5	25.5	Driving dynamo with load: stopped to excite dynamo field separately.
6	–	Current through field magnets (142.3 Watts)
7	–	Driving dynamo on open cct: through separately excited field.
8	15.4	- - - load
9	50.6	- - - - full load on motor.
10	49.9	- - - - - - - -
11	49.4	- - - - - - -
		Stopped test. Temp: of air within motor armature 40°c.



Test of the efficiency of a small ⅛ H.P. C.C. Motor.

12th October 1890.

The small ⅛ H.P. B.R.C. motor weighing 16 lbs. 11 oz. = 7570 grammes has an armature resistance cold of 16 ω and inductance of 800 kilometres with the field magnets unexcited or 736 kilometres in excited field. The field magnets have a resistance of 320 ω cold. (20°C) and an approximate inductance of 23·17 earth-quadrants. ($\frac{100000}{1000}$, 071, 3310) This motor was placed on the float of a Webb dynamometer, and connected with a small Paris ⅛ H.P. motor which it ran as a dynamo through a spiral spring. Results as follow:—

No.	Time	Revs. of pan min	machine per sec	P.D. on motor.	Shunt reading.	Amperes this motor	Energy absorbed by motor	Scale reading	Torque	Energy delivered by motor	P.D. on dynamo terminals	Sp. g. reading for dynamo 1 sec.	Amperes in dynamo test.
1		–	–	119	0.075	0.379	45.1	–	–		–	–	–
2		3200	53.3	"	0.125	0.63	75	–	–	–	–	–	–
3		"	"	"	0.131	0.661	78.7	50 @ 6				–	–
4	15.35	2850	47.5	118.7	0.207	1.045	122.3	100 @ 10 50 @ 9	300	59.80	–	–	–
5	15.40	2775	46.3	116.7	0.245	1.237	144.4	100 @ 20 50 @ 12	1950	72.85	76	2.42	0.336
6	16.00	–	–	118.0	0.065	0.358	42.3	–	2600		–	–	–
7	16.05	3025	50.4	117.0	0.150	0.763	89.3	100 @ 5 50 @ 7	850	26.4	–	–	–
8	16.09	3050	50.9	118.0	0.190	0.960	113.2	100 @ 10 50 @ 8.5	1425	44.7	110	10.30	0.140
9	16.15	2650	44.2	117.0	0.297	1.50	175.5	100 @ 30 50 @ 18	3920	106.3	83	39	0.610
10	.30	2600	43.3	"	0.291	1.47	171.9	100 @ 20 50 @ 35	3750	100.1	81.7	–	–
11	.50	2600	43.3	"	0.287	1.45	169.6	"	"	"	80.9	"	"

The results obtained are:—

	Watts
Power required to excite motor fields	42·3
" " " run armature to speed	30

The resistance of the armature hot being 18 say, the efficiency of the machine as commercially at 118 volts

$$\frac{c(118 - 18c) - 30}{118c + 42.3}$$

at 1·14 amps $c = 1.14$ this becomes $\frac{101}{176.8} = 0.598$

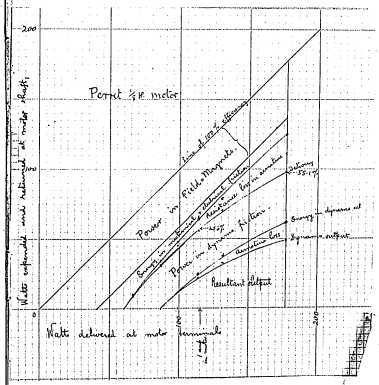
As observed it was $\frac{106.3}{175.5} = 0.606$

The general formula is

$$\eta = \frac{\left(c - \frac{c}{340}\right)\left\{e - 18\left(c - \frac{c}{340}\right)\right\} - 10}{ec}$$

2 × 3.1416 × 981 = 6166

	Intake				Calculated Loss			Output			
Time of Obn.	P.D. on motor Volts	Shunt Amps	Current through motor Amps	Energy on motor Watts	Energy in armature Watts	Calculated Friction in armature Watts	Difference	Revs. per min.	Revs. per sec.	Scale Rdg	Torque Grams
.1	123	0·065	0·328	40·4	-						
.2	122	0·097	0·490	59·9	19·4	0·4	19·0	2900	48·3	-	-
.3	121·5	0·109	0·550	66·8	26·4	0·8	25·6	2850	47·5	50 g @ 6	300
.4	120·5	0·141	0·712	85·8	45·4	~~2·5~~	~~42·9~~	2980 ?	44·7	{100 @ 5 / 50 @ 12}	1100
.5	120	0·143	0·722	86·6	46·2	2·9	43·6	2834	47·2	"	1100
.6	121·5	0·162	0·818	99·4	59·0	4·1	57·9	2808	46·8	{100 @ 5 / 50 @ 25}	1575
.7	118	0·191	0·965	113·9	73·5	7·1	66·4	2704	45·0	{100 @ 10 / 50 @ 30}	2000
.8	117	0·221	1·116	130·6	90·2	10·9	79·3	2574	42·9	{100 @ 20 / 50 @ 38}	2650
.9	116	0·307	1·55	179·8	139·4	26·8	112·6	2223	37·0	{100 @ 25 / 50 @ 50}	4400
.10	116·5	0·302	1·525	177·7	137·7	26·8	110·9	2184	36·4	"	"



Efficiency test of the ½ H.P. Perret Motor.

The Perret motor weighs 17lb 3oz is marked 2200 rev., 110 volts, 1 amp. Its armature resistance was 17.0 ω the field resistance 314 ω. The motor was flouted and connected to drive the C.-B.

Energy Delivered		Delivery: D.D. on dynamo volts	Stat. g. reading	Turns	Amperes	Energy delivered watts	Calculated Cm in amps	Remarks
	field							Field of motor excited
	90							Motor armature running light
6.8	44							- - coupled to dyn. arm.
30.3	44	92						- - - - - dyn. field excited
32.2	44	94						- - - - - load commenced
45.5	42	93	8°55′	0.1568	0.118	11.0	0.2	1.12 - - - - - - -
55.5	40	84	19°30′	0.3541	0.267	22.43	1.1	1.235
70.1	38	78	29°	0.5543	0.418	32.6	2.9	1.375
100.4	35	57	49°25′	1.1672	0.880	50.2	12.4	1.626 Full load
98.7	34	55.5	49°30′	1.1705	0.882	49.0	12.5	1.5 After one hour

The temperature on the surface of the armature after one hour's run was 64° C.

The efficiency of this motor is

$$\frac{c_a\left\{c - 18\frac{c}{360}\right\} - \frac{c_a^2}{360} - f}{cc}$$

where c is the emf at machine terminals

c_a - - current through the armature

c - - - - - - machine

f - - power in friction

$c_a = c - \frac{c}{360}$

f = a function of c and c but for moderate loads 10

$$\therefore \eta = \frac{\left(c - \frac{c}{360}\right)\left\{c - 18\left(c - \frac{c}{360}\right)\right\} - \frac{c_a^2}{360} - 10}{cc}$$

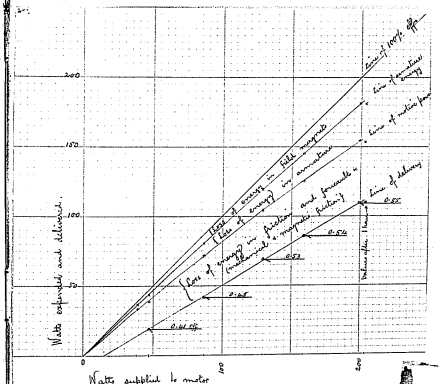
The last observation gives

$$= \frac{\left(1.525 - \frac{116.5}{360}\right)\left\{116.5 - 18\left(1.525 - \frac{116.5}{360}\right)\right\} - \frac{(116.5)^2}{360} - 10}{116.5 \times 1.525}$$

$$\frac{1.202 \times \{116.5 - 21.6\} - 32.37 - 10}{177.6}$$

$$\frac{104.1}{177.6} = 58.6\ \%$$

No. of Obs.	P.D. on motor volts	Obserd. Amp.	Amperes in motor	Energy in motor Watts	P.D. on field	Energy in field	P.D. on armature	Energy in Arm.	Mechanical loss in arm.	Difference	Revs. per min.	Revs. [illegible]
1	11·8	0·65	3·28	38·7	0·557	1·827	11·24	36·87	2·69	34·17	3255	54·
2	10·35	0·89	4·49	46·5	0·763	3·426	9·59	43·07	5·04	38·03	1612	26·1
3	14·55	1·18	5·96	86·7	1·013	6·037	13·54	80·7	8·88	71·82	1907	31·
4	16·4	1·56	7·88	129·3	1·34	10·56	15·06	118·7	15·52	103·28	1811	30·
5	17·8	1·77	8·94	159·2	1·52	13·59	16·28	145·6	19·98	125·6	1811	30·2
6	19·3	2·05	10·35	199·7	1·76	18·22	17·54	181·5	26·78	154·7	1845	30·7
7	19·6	2·06	10·40	203·8	1·77	18·41	17·83	185·5	27·04	158·5	1800	30·

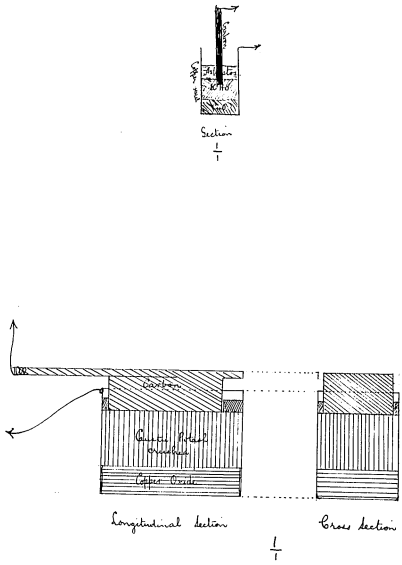


Test of Efficiency of Crocker & Wheeler
1/4 HP. low-volt series motor.

The weight of this motor is 29 lbs, 8 ~~ounces~~ and its armature 0.25 ω (hot) is in series with its field 0.17 ω (hot). The following results were obtained :-

Revs. per min.	Revs. per sec.	Scale Reading.	Torque in gm.	Energy delivered	Calculated friction		Efficiency	Remarks.	
3255	54.25	–						Running light + disconnected	
1612	26.84	500 ⊙ 23	1150	19.0	19.03		0.4085	Connected to dynamo armature	
1907	31.8	{100 ⊙ 5 500 ⊙ 20.3}	1515	29.7	42.1		0.4884	" " "	- field excited
1814	30.23	{100 ⊙ 25 500 ⊙ 21.5}	2675	68.5	34.8		0.53	load applied	
1814	30.23	{200 ⊙ 20 50 ⊙ 12}	4600	85.76	39.8		0.539	–	.
1845	30.75	{200 ⊙ 20 50 ⊙ 20.3}	5760	109.2	45.5		0.547	–	–
1800	30.0	{200 ⊙ 20 50 ⊙ 20.5}	5925	109.6	48.9		0.538	After one hour	

Temp: on the armature rose to 40°C, after the hour run.



Test of a new Thermo-Electric Element

17th October 1820.

A small copper cylinder about 2 cms long and 1 cm in diam. closed at one end was used as one plate of the cell, into the bottom was poured some coarsely powdered Calamine (battery) copper oxide. Above this some crushed caustic potash. Into this layer of potash a small stick of carbon was introduced, supported by a disk or cover of asbestos. The carbon stick formed the other pole of the cell. The resistance between the outer and inner pole was about 20000 w by bridge. A powerful blowpipe flame was then applied to the cell. Connecting the terminal to the potentiometer the first emf detected was from the carbon externally to the copper. As the temperature of the cell increased, this emf diminished, passed through zero and became reversed, the copper now being positive external to the carbon, so that the carbon took the place of zinc in an ordinary battery. At a bright red heat, the emf so observed was 0.33 volt not quite steady.

Repetition of this test on 20th October.

The cell represented on the opposite page was here tested. The same general phenomena presented themselves namely a normal cold res. of 500 w, an emf on heating diminishing vanishing and reversing. When the carbon was red hot and the caustic potash boiling over, the emf observed reached 0.67 volt at which time it gave a steady current through leads and Steinens tom galvo (1.5 w cst) of $65° = \frac{2.0146}{7.66} = 0.29$ amp. from which the int: res: would be 0.8 w. This current was observed for about 15 seconds. On again taking the emf it was found to have fallen to 0.24 volt above which value it did not again rise. This fall in emf may have been due to thermo-electric changes in the cell or chemical alteration of the surfaces. The resist. measured in the cell by potentiometer was 10 w. The galvo: indicating $22° = \frac{0.409}{7.66} = 0.053$ amp $\doteq 3.5$ w. int: res: The readings were all unsteady.

On the best value of the Standard 0.01 w.

These values of the 0.01 w are not reliable enough. The left may be nearer the truth. See p. 163 III

The original determination 7. II. 89 (I. 82.) was 0.00982
Legal w @ 16.5°C. or @ 0°C. 0.009785

next 18. VI. 89 (I. 135) was 0.009833
Legal w @ 23.5°C or 0.009784

next 20. VI. 89 (III. 144) was 0.009825
Legal w @ 24.5°C or 0.009774

Mean @ 0°C. 0.009781

On the best value of the 2000 amp. Shunt, L.w @ 0°C.

On the first good determination 18. VI. 89 (I. 135) 0.001627 Wt 2.0355. 0.001619
next 21 X 90 (2. 144) 0.001620 Wt 3.022 = 0.001613
0.001626 = 1.0 2.25. 0.001626

General mean 0.001617 w @ 0°C all in terms legal ohm

Standard = 1.00028 ω @ 16.9°C.
23
1.00258

24.5
7.6 × 0.03 = 0.23

1) $\frac{100 \times 6760}{6860} = 98.52$ ω.

$\frac{0.009867 \times 6760}{6808} = 0.009799$ @ 24.5°C. × Log. 10
$= 0.009825$ @ 24.5°

2) $\frac{15 \times 6760}{6775} = 14.97$ ω

$\frac{14.97}{9400} = 0.001592 \times 1.00258 = 0.001596$

3) $\frac{1800 \times 6760}{8560} = 1421.5$ ω

$\frac{1421.5}{1421.5 + 7078 + 2.4920} = 0.001672 \times 0.9825 = 0.001643$

4) $\frac{6760}{6760 + 24.920 + 7557} = \frac{6760}{3924.247} = 0.001722 \times 0.9825 = 0.001692$?

Comparison of Standard Resistances previous to a conductivity measurement.

24th October 1820

No. of Obs.	Temp. of Std. Res.	Res. of Std. Temp.	Temp. of Wire	Resist. of Cylinder	Ratio	Corrected Ratio	Res. of 0.01		Res. of 0.01 at 0°C	Temp. at which correct	Coeff.	Weight	Mean
1	24.5°C	1.00258	24.5°	6760	0.010	0.009774	0.009825		0.009774	107.0°	1.00021		
2	24.5°	1.00258	24.5°	6760	0.0149	0.001592	0.001596					(2)	
3	24.5	0.009825	24.5	6760	0.001672	0.001644	0.001643	0.001644	0.001643		1.00021	(2)	0.001644
4	24.5°	0.009825	24.5°	6760	0.001722	0.001692	0.001692					(1)	

Measurement of Conductivity and Tenacity of a sample of Silicon Bronze Trolley wire

The weight of a short length was first taken

No. of Obs.	Length of sample	Weight oz.	grains	Weight grammes	grammes per cm.	grammes per mile	lbs. per mile	grammes per c.c.	Sp. g.	Lbs per ft.
1.	80.95	7	120	198.5 7.78 206.28	2.5475	4.10,000	903.8	8.806	8.806	0.7764 = 0.17 lb.

The diameter

No. of Obs.	Diameter observed inches	Mean	v	Σv^2	Σv^2	r_1	Σv	r_2	Final Result
1	0.2392		−0.0003	9 × 10⁻⁸					
2	0.2391		−0.0002	4		0.04097 × 10⁻⁴		0.01242 × 2v	
3	0.2391		−0.0002	4					
4	0.2390		−0.0001	1					
5	0.2393		−0.0004	16					
6	0.2392		−0.0003	9					
7	0.2389		0						0.2389"
8	0.2391	0.23890	−0.0002	4	120	0.4663 × 10⁻⁴	0.0038	0.0000471	± 0.00005"
9	0.2386		+0.0003	9		±0.00005		0.00005	(0.60680 cm ±0.00012)
10	0.2388		+0.0001	1					
11	0.2386		+0.0003	9					
12	0.2382		+0.0007	49					Cross section 0.04483 sq. in.
13	0.2386		+0.0003	9					
14	0.2389		± 0	1					0.2988 cm
15	0.2390		−0.0001	1					
16	0.2390		−0.0001	1					
17	0.2387		+0.0002	4					

Specific Gravity by Direct Measurement (Fragar & A)

for 2 more see next page

Weight in air 12.3281
" water 10.9523
1.3758 temp. of water 24°.
× 0.99727 = 1.3724 = 8.940

$2707 + 2955 = 5662 \div 2707 = 2.092$

$2707 + 1590 = 4397 \div 2707 = 1.6242$

$2707 + 1020 = 3727 \div 2707 = 1.377$

$2707 + 220 = 2927 \div 2707 = 1.0813$

$5940 + 2707 = 8647 \div 2707 = 3.195$

$615 + 2707 = 3322 \div 2707 = 1.227$

Tests of Sample of Silicon-Bronze Trolley Wire contd.

(165)

Three lengths were measured from a fixed mark by tape line.

No. of Wire	Length by tape line 1st kind	Length by tape line 2nd kind	Length by tape line 3rd kind	Mean	v	v^2	Σv^2	$\sqrt{\ }$
1	1402.1	1402.5	1402.6	1402.4	0.3 -0.1 -0.2	0.09 0.01 0.04	0.14	± 0.10
2	1089.9	1090.2	1090.25	1090.09	0.2 -0.1 -0.1	0.04 0.01 0.01	0.06	± 0.068
3	924.0	924.15	924.2	924.07	0.07 -0.08 0.01	0.0049 0.0064 0.0001	0.0238	± 0.040
4	724.5	724.7	724.7	724.63	0.13 0.07 0.07	0.0169 0.0049 0.0049	0.0267	± 0.045
5	355.4	355.45	355.45	355.43	0.03 0.02 0.02	0.0009 0.0004 0.0004	0.0017	± 0.011
6	136.0	136.0	136.1	136.03	0.03 0.03 0.07	0.0009 0.0009 0.0049	0.0067	± 0.023

Galv. D. B. Differential 1+1 B. checked. Res. 2707 ω per coil
150 ω set with ωs: hand coil for balance.

No. of wire	Length	Res: added	to	Ratio	Standard	temp.	Res: of std	Res: of wire ω	Res: per cm ω	Resistivity
1	1402.4±0.1	2955	wire	2.092	0.01	22°C.	0.00980 (0.00980-57)	0.020502 (0.020502-57)	14.621 (14.621-3)	4224 3872 4.2011
2	1090.0±0.07	1690	"	1.6242	-	-	-	0.015842 (0.015842-65)	14.600 (14.600)	4224.6 4224.7
3	924.1±0.04	1020	-	1.377	-	-	-	0.013495 (0.013535)	14.605 (14.645)	4223.5 4235.6
4	724.6±0.05	220	-	1.0813	-	-	-	0.010600 (0.010603)	14.625 (14.667)	4229.3 4247.4
								Mean	14.658	
								Res per mile	2.358 ω	
5	355.4±0.4	5940	-	3.195	0.00163	-	0.00163	0.005207	14.650	4236.5
6	136.0±0.02	615	-	1.227	-	-	" "	0.002000	14.710	4253.8

Mean Resistance of strip 2000 amp. by this $\frac{0.001163 \times 14.615}{14.680} = 0.001620$ @ 22°C.

No. of wire	Resistivity	Mean	v	v^2	Σv^2	$\sqrt{\Sigma v^2}$	$0.1947\sqrt{n}$	Result	Resistivity of copper @ 20.5°C.	% Cond.
1	4224.8 (4.2011)	4226.35 4.238.5	-1.65	2.722	22.610	4.76	±0.927	4226.4±0.9 4235.5±0.9	17524	41.5 41.37
2	4224.6 (4.2016)		+1.75	3.062						
3	4223.5 (4.2356)		+2.85	8.123						
4	4229.3 (4.2474)		-2.95	8.703						

∴ True result probably within limits 0.001927

Specific Gravity Measurements by Frazar. temp Water 24°C.

Trial No.	Weight in air	Weight in Hg. dist.	Loss.	Sp. gr. of water (distilled)	Sp. g.	Mean Sp. g.	Weight per cm³ gms.	Wt per ft gms.	Wt per mile gms.	
1	12.3281	10.9523	1.3758	1.3795	8.940	8.941	2.586	78.78	46,100	
2	12.3281	10.9523	1.3758	1.3795	8.940					
3	12.0217	10.6808	1.3409	1.3445	8.942			0.1737 lbs	917.2 lb	

Tests of Silicon Bronze Trolley Wire

Breaking Strain. This was determined by pulling up a piston in a cylinder filled with oil. The pressure was observed on a pressure gauge and also by an indicator area of piston 77.056. Two trials. Both resulted in fair fractures, between loops

First reading	39 lbs. on gauge	37 on indicator	2850 lbs	63,610 lbs per sq. in.
Second -	45 - - -	41 . -	3160 -	70,480

Three trials were then made of ductility:—

1st gave	12 twists in 12 inches	or 3.5 per inch	
2nd -	13 - - 6	. 2.2 - -	
3rd -	18 - - 5	. 3.6 - -	

The last specimen was from a piece that had undergone the breaking stress. ※

Measurement of radius of moon's corona 22nd Oct. 90

At 19.20 the mean distance in arc from the moon center to the mean coronal circle measured 21½° by sextant. Night very calm, but misty.

Measurement of the refractive index of liquid bimesmine for the D line

The angle of the prism = 58°. 53'. 5"

. angle of minimum deviation = 42°. 27. 20"

$$\therefore \mu = \frac{\sin \frac{1}{2}(101^\circ + 17'.25'')}{\sin(29^\circ.26'.32'')} = \frac{\sin(50^\circ.38'.43'')}{\sin(29^\circ.26'.32'')} = \frac{0.7732}{0.4918}$$

$$= 1.573 \quad \text{Temp. } 23^\circ C$$

With another prism filled with distilled water

The angle of minimum deviation = 22°. 50'. 0"

- - prism = 59°. 22'. 0

$$\mu = \frac{\sin \frac{1}{2}(82^\circ.12'.0'')}{\sin(29^\circ.41'.0'')} = \frac{\sin(41^\circ.6')}{\sin(29^\circ.41')} = \frac{0.65738}{0.49321}$$

$$= 1.3275 \text{ for D. line @ } 20^\circ C.$$

※ Third test of breaking stress 20th Nov. 1820 gave following result. Same conditions as above fair break, pressure gauge 40 ; Tabor indicator 42 . Taking 41 lbs. 41 × 77.06 = 3160 lbs. pull = 70,480 lbs. per sq. in.

Revision of wire guages needed for the Milwaukee Railroad Model

Corrected for Scale Error.

The scale of the map is 600 ft to 1". or 1 mile of 5280' is 8.8"

The resistances per foot of the experimental sizes of wire are —

No. of wire	C Mils	Doubled for models	Res. per foot	Res. per foot of doubled	Res. per mile	Res. per mile doubled wire	Res. of models wire per foot	Diameter C. mils	Best size	Diam.	C mils
1	390,625	781,250	2.688×10^{-4}	1.344×10^{-4}	1.4195×10^{-3}	7.1×10^{-4}	7.1×10^{-3}	9.62×10^{-3}	10,330		
2	250,000	500,000	4.20 "	2.10 "	2.218 "	1.109×10^{-3}	1.109×10^{-3}	0.01512	6614	# 23	0.0225	625"
3	180,625	361,250	5.81 "	2.905 "	3.069 "	1.535×10^{-3}	1.535×10^{-3}	0.02093	4778	# 24	0.022	484
4	144,000	288,000	7.29 "	3.645 "	3.850 "	1.925×10^{-3}	1.925×10^{-3}	0.02625	3809	# 25	0.020	400
5	115,000	230,000	9.13 "	4.565 "	4.821 "	2.410×10^{-3}	2.410×10^{-3}	0.02886	3464	# 26	0.018	324
6	56,000	112,000	1.875×10^{-4}	9.375 "	9.90 "	4.95×10^{-3}	4.95×10^{-3}	0.0675	1485	# 30	0.0120	144

On the completion of this model, the fall of potential at the end of National Avenue was almost 25%, while at the end of the other long avenue it was generally about 20.

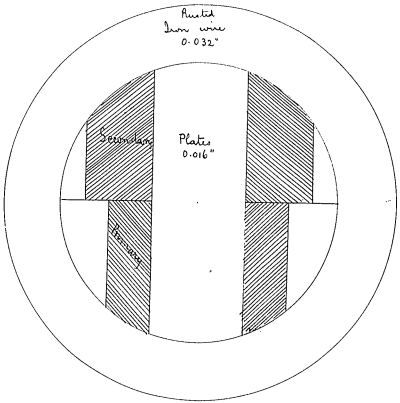
On a determination of the best size of wire to employ with a double-cotton covering on an experimental armature with deep grooves but on the same general dimensions as that detailed on p. 132.

The breadth of solid core to be 1" as before, the depth of grooves to be 3/8" 0.375, and the breadth 0.2254" as before. The free winding breadth allowing for body insulation = 0.1854" and the free depth 0.360". Two wires to one layer = 0.0368" each covered or with 0.011" collar 0.0225" say # 23 B.W.G. or 6225 c. mils. There would be 10 layers or 0.360 deep. The res. would be $\frac{8}{25}$ = 3.2 ω. Number of turns per block 50. Commutator bars 42 as before 2100 turns in all. The weight of wire on the present armature being 15 oz. Then will be $\frac{625}{256}$ = 2.5 × 15 = 38 oz. and the whole armature will weigh about 10 lb.

4

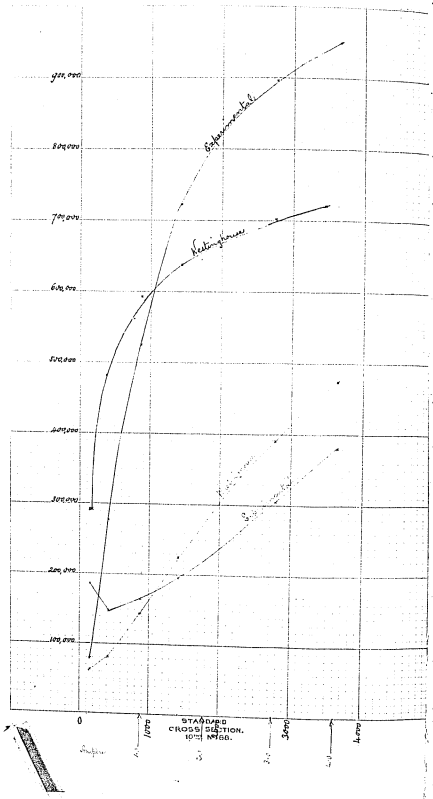
Full size

Cross section



Length of cylinder	20.4
. over wire	27.

Weight of primary		2.75 lbs.
. . secondary		3.44 .
		6.2 .
. . iron		39.
Total . .		45.2 .



Test of Edison Experimental Transformer #4.

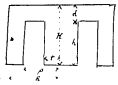
(143)

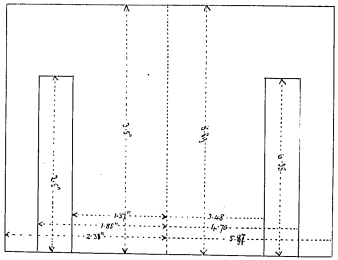
22nd October 1820.

Primary 720 turns Secondary 35

No of Hr	EMF Source	EMF	Capacity	Q	Mean Power	q per div.
	3 C. Cell. @ 22.5°C	4.29×10^{1}	$1\,9 \times 10^{-15}$	4.29×10^{-7}	168.6	2.56×10^{-9}

No	Stat. G.	Tan.	Obsch.	Amperes	M.M.F	No. of Turns	Means	Resistance	l. of G. ect	ϕ	$\frac{M}{\phi}$	
1	12°.15'	0.21712		0.1637	1458.2	4	72	25,000	30,250	79,640	1.86×10^{-3}	Experimental
2	31°.5'	0.6028		0.4546	4115	3	252	–	"	278,800	1.476	
3			0.190	0.959	868.2	2	260	50,000	55,250	525,300	1.653	
4			0.310	1.565	1417	4	187.5	100,000	105,250	721,800	1.961	
5			0.600	3.030	2743	3	233	"	"	896,600	3.059	
6			0.790	3.990	3612	4	247	"	"	957,700	3.799	
1	15°.10'	0.27107		0.2044	185	4	145	50,000	55,250	293,000	6.312×10^{-3}	Westinghouse
2	30°	0.57735		0.4357	394.1	4	229	"	–	483,000	8.158	
3	51°.30'	1.25717	0.190	0.859	862.5	3	294	"	–	594,100	1.452×10^{-3}	
4			0.316	1.596	1445	3	166	100,000	105,250	638,800	2.262	
5			0.60	3.03	2743	2	182.5	–	–	702,200	3.905	
6			0.75	3.79	3431	3	187.5	–	–	721,800	4.753	





Volume of Magnet 59.7 cubic inches
978 c.c.

" " Winding Space 12.14 cubic in.
200 c.c.

" " Weight of wire 2¼ lbs
1000 gms.

" " wire 47.56 c.i.
778 c.c.

Weight of wire. 14.25 lbs.
" " 6070 gms.

" " magnet 16.5 lbs.
" " 7070 gms

Surface of pole 58.97 sq. in.
38.05 sq. cms

" " tube 5.90 sq. in.
" " " 38.1 sq. cms

lbs. weight per sq. in. 169.5

Density in pole surface 17,300

Problem:— To determine the best dimensions of a tubular electromagnet that will give a certain lifting power with the minimum of weight.

Let s be the surface of the pole necessary for the required pull.
σ - - specific gravity of wrought iron
v - - volume of winding space necessary.
and the other dimensions as shown
W - - total weight of the magnet.

Then
$$s = \pi r^2 = \pi (R^2 - \rho^2) = 2\pi r d \qquad (1)$$
$$v = \pi h (\rho^2 - r^2) \qquad (2)$$
$$W = \sigma \{ \pi (h+d) R^2 - v \} + k \qquad (3)$$

and substituting
$$R^2 = \frac{s}{\pi} + \rho^2$$
$$= \frac{s}{\pi} + \frac{v}{\pi h} + r^2$$
$$W = \sigma \left\{ \frac{\pi (h+d)\left(\frac{hs}{\pi h} + v + h\pi r^2\right)}{\pi h} - v \right\} + k$$
$$\frac{dW}{dh} = \sigma \left\{ \left(\frac{d}{h^2}\right)(hs + v + h\pi r^2) + \left(\frac{h+d}{h}\right)(s + \pi r^2) \right\}$$

For a minimum
$$\frac{h+d}{h}(s+\pi r^2) = \frac{d}{h^2}(hs + v + \pi h r^2)$$
$$h(h+d)(s+\pi r^2) = d(hs + v + \pi h r^2)$$
$$h\pi r^2 + h^2 s + hds = hds + dv$$
$$h = \sqrt{\frac{dv}{s+\pi r^2}}$$
$$= \sqrt{\frac{dv}{2\pi r^2}} = \sqrt{\frac{v}{4\pi r}}$$

Allowing 170 lbs per sq. in: of polar surface, for a total lift of 2000 lbs we need $\frac{2000}{2\times 170} = 5.88$ sq. in:
for which the diameter $= 2.7$ in.

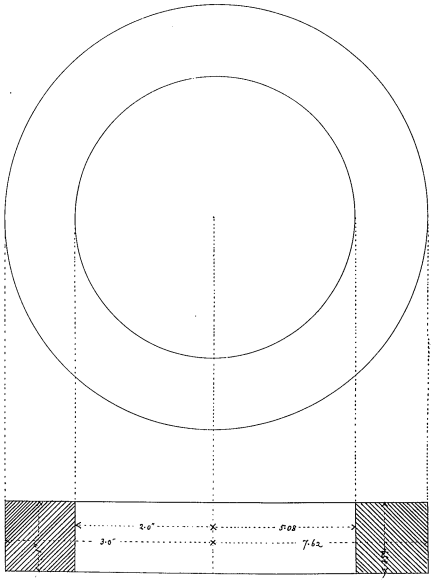
The weight of copper = say 5 lbs. = 27.5 cub. in.
$$h = \sqrt{\frac{27.5}{12.57 \times 1.37}}$$
$$= \sqrt{1.599} = 1.26'' \text{ say } 1.5''$$

Say 1 coils h = 5.5 cubic in. =

Then $\rho^2 - r^2 = \frac{27.5}{1.5} = 18.3$

$\rho^2 =$

Full size plan and diametrical section of test ring transformer



Outer circumference 18·85", 47·8g. Inner circum. 12·57", 31·92. Mean 15·71", 3

Size of iron wire in core # 28 B.W.G. 0·032" 0·0813

31 Turns per layer 31 layers. 968 turns in all.

Thickness of rust estimated 0·00075". 0·0019

Diameter of iron in wire 0·0305". 0·0775

Area of wire 0·00801 □" 0·05167 □cm Area of iron in wire 0·00731 □in 0·0471

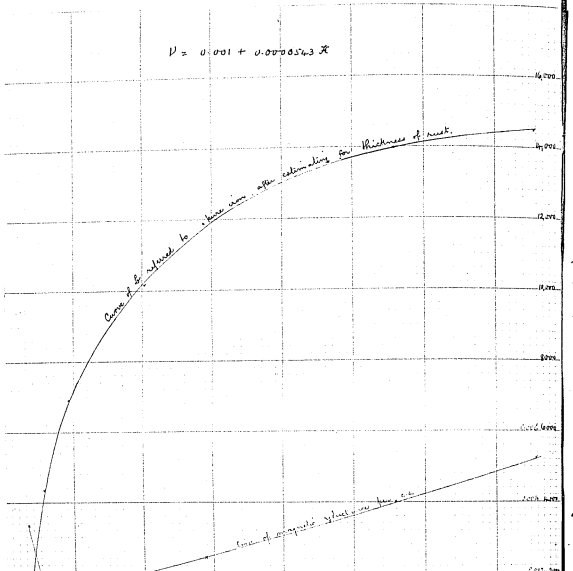
Factor of reduction. 0·9092 Total area of iron wire 0·7982 □in 5·020

Total area of iron 0·7073 □in, 4·563 □cm. Cross section of core 1·4 □in

Factor of tot. reduction. 0·707 Volume of core 15·77 cubic inches 257

Volume of iron wire 12·23 c.i. 200·4 cc Volume of iron 11·11 c.i. 182·1

Observed weight 3 lbs 3 g = 1445·5 Sp g. of wire 7·212 Mean Sp.g. of core 5·616



Tests of the Ring Transformer represented on the opposite page (50)

24th October 1820.

Two coils are wound upon this ring as shewn:-

1st 580 turns of #23 BWG. 0·025" = 0·064 cm. 215·8 in length 6552 mm averaging 0·3707' or 11·3 cms per turn, the weight being 6·75 g. or 191·4 gm. = 0·00196 lbs per ft.

2nd 108 turns of #16 BWG. 0·065" = 0·165 cm, 40·0' in length 1219 cm. averaging 0·3705 or 11·29 cm. per turn, the weight being 5·5 g. or 156 gm = 0·00359 lbs. per ft.

Capacity	Source of EMF	Value of EMF	Q	Mean Throw	Q per div.	No. of Throws
1 μ	3 C.C. @ 23°C	$4·287 \times 10^{8}$	$4·287 \times 10^{-7}$	167·25	$2·563 \times 10^{-9}$	6

Mag. No.	Std. G.	Bench.	Tan.	Ampere	MMF.	No. of Throws	Mean Throw	Res. in ecl.	Res. of g. ecl.	Φ	$\frac{\Delta\Phi}{\Delta i}$	$\frac{\Delta\Phi}{\Delta i}\left(\frac{\Delta i}{\Delta H}\right)$
1	12°·55'		0·2293	0·1729	126·1 3·161	4	68·5	–	5250	42,65	935	
2	22°·00'	~~0·103~~	0·4040	0·3047	222·2 5·571	5	55·6	25,000	30,250	19,960	4374	1·27
3	34°·30'	0·103	0·6873	0·5183 0·507	369·7 9·271	4	87·6	"	"	31,450	6894	1·345
4	56°·15'	0·221	1·4966	1·129 1·111	810 22·31	3	129·3	"	"	46,410	10,170	1·997
5	64°·45'	0·312	2·1203	1·599 1·573	1148 28·78	4	151	"	"	54,210	11,880	2·423
6	74°·	0·505	3·4874	2·63 2·55	1860 46·63	4	172·6	"	"	61,960	13,580	3·434
7	76°·15'	0·605	4·0867	~~3·083~~ 3·055	2229 55·86	5	177·5	"	"	63,710	13,960	4·001
8	80°·0'	0·82	5·6713	~~4·277~~ 4·140	3019 75·7	3	184	"	"	66,060	14,480	5·228

Resistance and Inductance of coils.

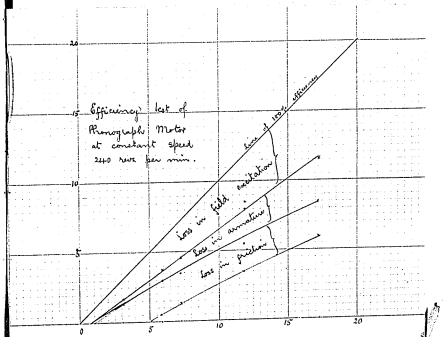
Coil #	Bridge Ratio	Coeff.	Resistance unplugged	Res.	Fund.	Tun. Res. @ 23°C.	Inductance Quadrant	Inductance Kilometric	Mutual Quadrant	Indi. Kilometric	$\sqrt{L_1 L_2}$	Acceptd. Resultn. Kilometric
1	$\frac{10,000}{100}$	0·84	21·50	0·215	0·09	0·122	0·1806	1,806 (Brass)				18·06
2	$\frac{14,000}{100}$	0·063	7361	73·61	70·09	3·52	4·637	46,370				
3	$\frac{18,000}{100}$	0·195	2363	23·63	20·09	3·54	4·6080	46,080	(Brass)			46·33
4	$\frac{18,000}{100}$	0·3[illegible]	1363	13·63	10·09	3·54	4·6610	46,610				
5	$\frac{10000}{100}$	0·371	13625	13·625	10·09	3·535			0·3912 0·4287	3912 4287	2·9092	42·5
6	$\frac{10,000}{100}$	0·308	13625	13·625	10·09	3·535						

Inductance by discharge test.

No. #	Coil	Std. g.	Tan.	Amp. Div. m	No. of Throws	Mean	Mean + accepted	res. of g. ecl.	a	$\frac{\pi y}{c}$	L Kilometric
1	Brass			0·0715	10	0	4?	5250	$10·26 \times 10^{8}$	$7·53 \times 10^{8}$	75·3
2	Fine	28°·20'	0·084 0·543	0·01409 0·014895	9	139	145 139	52,250 "	$37·16 \times 10^{8}$ $35·63 \times 10^{8}$	$4·76 \times 10^{8}$ $4·57 \times 10^{8}$	476 457

There was a spark visible at the contacts on every discharge. The key contacts were set very close, and the release made as sharp as possible. The result with the fine wire coil is remarkably close to the secohmeter measurement.

No. of Obs.	P.D. on Motor in volts	Amperes per motor	Energy taken by motor	Current thro' field in amperes	Energy taken by field	Current thro' armature in amperes	Energy in armature	Full of fet. in armature	Counter emf in armature	Loss of energy in armature	Total loss of energy
1	1·52	2·914	3·101	0·861	1·309	1·179	1·792	0·277	1·243	0·326	1·635
2	2·0	2·904	5·808	1·133	2·266	1·771	3·542	0·416	1·584	0·737	3·003
3	2·15	3·358	7·218	1·218	2·618	2·140	4·600	0·503	1·647	1·076	3·694
4	2·50	4·722	11·805	1·417	3·504	3·305	8·301	0·777	1·723	2·569	6·173
5	3·16	5·460	17·260	1·791	5·659	3·669	11·609	0·862	2·298	3·163	8·820
6	3·60	5·504	19·820	2·040	7·344	3·464	12·476	0·814	2·786	2·820	10·164
7	2·62	4·671	12·240	1·485	3·890	3·186	8·350	0·749	1·871	2·386	6·276



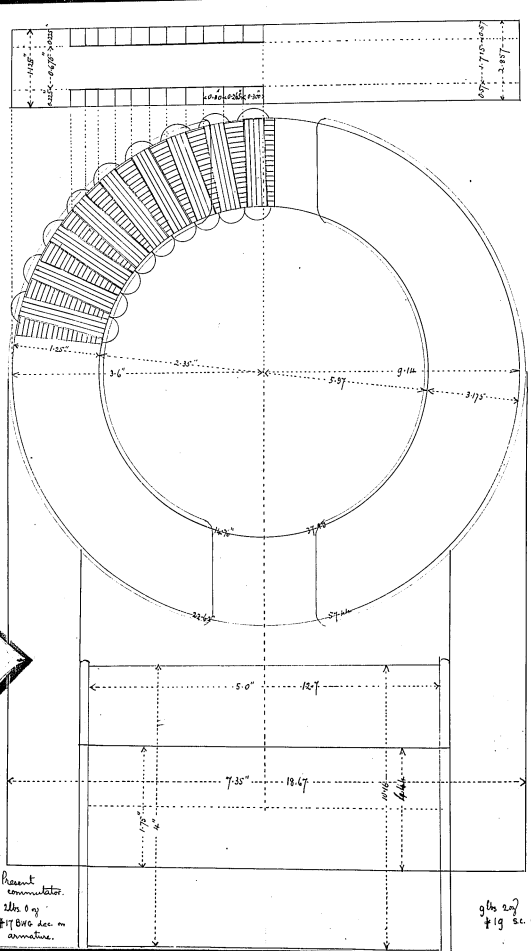
# of revs. in number	Total loss of energy
3.326	1.635
1.737	3.003
1.076	3.694
2.569	6.173
1.163	8.820
2.820	10.164
2.386	6.276

Efficiency test of the Phonograph Motor.

This motor is one that was made at the Factory taken at random and used to run a commutator. The resistance of its four field coils in series (warm) was 1.765 ω, and of its armature between brushes 0.235 ω. These standard resistances are 1.8 ω and 0.250 ω respectively. It was mounted on the float so that its axis ran horizontally, and following are readings

Total calculated useful energy	revs. per min	revs. per sec.	Scale Rly	Torque	Energy delivered	Friction	% of Eff.	Armature emf per sec	Remarks
1.466	235	3.917	50 @ 0					0.39	Armature running light
2.805	244	4.066	50 @ 2.7	.135	0.826	2.479	5.61	0.395	Coupled to dynamo
3.524	248	4.133	50 @ 7.0	.350	0.892	2.632	12.36	0.396	dynamo field excited
5.632	232	3.867	50 @ 22.	1.100	2.622	3.010	22.2	0.405	Loaded
8.440	250	4.167	50 @ 31.3	1.565	4.020	4.420	23.29	0.351	"
9.656	285	4.750	50 @ 31.2	1.563	4.079	5.077	23.10	0.356	After one hour
5.964	240	4.00	50 @ 28.4	1.420	3.502	2.462	28.62	0.368	" "

After one hour run the temperature on the armature was 79° F. The e.m.f generated for 1 rev. per sec. in the armature is say 0.4 volts. The speed at which the phonograph runs may be set at 110 revs. per min = 1.83 per sec. and the velocity ratio of the cylinder to the motor is $\frac{4.375}{2}$ = 0.6875, so that the velocity of the motor = 160 revs per min. = 2.7 per sec, and the emf 1.08. With 2.4 volts on the field the current = 1.205 amp., and the total average current being 2.3 amps. leaves 1 amp. in the armature = loss of 0.25 Watt. Total loss = (0.25 + 3.13) = 3.38 Watts, + delivered to motor 5.52 electrical efficiency = 2.14/5.52 = 38.76 %. The motor friction alone would be 1.1 Watts and the mechanical efficiency becomes 1.04/5.52 = 0.188



On the Electromagnetic design for a new model Phonograph Battery Motor of high Efficiency.

Data. The motor is to operate with governing margin on four Leclanché cells, and at a speed 50% in excess of that in the existing type, the external diameter being preserved. The energy to be utilised in motion is 2 Watts.

The emf of one Leclanché cell is after service 0.65 volts so that the emf of the battery is 2.6 volts. 1.2 amps flowing through its resistance (0.05×4 = 0.2) gives a drop of 0.24 volt and 0.06 in the leads gives an emf at m.t. of 2.3 volts. It is necessary therefore that for governing margin the emf generated by the motor must be 2.0 volts.

The present rotating speed is 160 revs. per min, so that we have for the given speed 2400 revs per min = 40 per sec.

$$\therefore \quad 4\,\phi w = 200,000,000$$

$$\phi w = 25,000,000$$

Let $w = 480$

$$\phi = 52,100$$

With $b = 10,000$ this gives 5.21 sq. cms. of cross section. The cross section allowed is 1.715 × 3.175 = 5.447 and with 4% pipe 5.2. The mean turn is 4.6" = 0.39 say 0.4' and 480 turns = 192'. The wire adopted is #17 BWG. 0.058" cond. to 0.070" in 40 grooves of 4 layers 4 wire wide. The res. of this wire per foot = 0.00307 ω. Res. of armature = 0.15 ω. The fall of pot: with one amp. through this is 0.15 volt or 7.5% of 2 volts. The energy lost 0.15 Watt. The breadth of groove = (4×0.070"+4×0.05") = 0.300", of the space (0.265"+0.05") (0.473 − 0.175).

The clearance is to be 0.03" on each side = 0.076 cms. The total air length 0.152. The mean polar area of iron is 1.3146 sq. cms × 16 × 2 = 43 sq. cms, so that the reluctance of the air gap is 0.00353. The reluctance of 15 cms of armature 5" in area = $\frac{3}{4}$ × 0.0005 = 0.00075 and 20 cms of field magnet 15 sq. cms in area = $\frac{20}{3}$ × 0.0005 = 0.0016, so that the total reluctance is 0.0059 lines. To drive 104200 lines through this requires 615 MMF = 489 say 500 A.T. allowing ½ of one ampere in the field circuit = 2500 turns.

For 15 sq. cms of magnet section 4.37 diam is needed = 1.75". The mean turn = 0.8'. ∴ total length = 2000 feet. This has to offer a resistance of 10 ω = 200' per ω. #19 BWG. nearest. = 9.124 lbs. of field wire. This will occupy 50.2 c.i. or with a core 5" long 10 sq. in. The area of the core being 2.405 sq. in + 10 = 12.405 = 4" diam.

With 2.0 volts at m.t. and 1 amp. passing through the armature 0.2 through the field, the energy absorbed = 2.4 Watts. The power in the field is 0.4 and in the armature 0.15 Watt. total loss 0.55 total useful energy 1.85 and efficiency electrical 77%. With 2 amperes in the armature the loss would be 0.3 Watt, the total 0.7, and the useful energy 4.4 − 0.7 = 3.7 the efficiency 84%.

The torque would be $\frac{480 \times 104,000 \times c}{6.28}$ = 7,846,600 × c dynes.

for 1 ampere 7,846,600 dynes = 800 grammes weight or 90 at the periphery. With 4 cells, the current would be approximately 2.6/0.4 = 6.5 amperes and the torque 5200 grammes weight or 580 at the periphery, at starting or when machine is held.

23·4
15·5
7·9 × 0·03 = 0·237 ft.

23·3
14
4·3 × 0·03 0·129 × 5 = 0·6445 = 5·00645

21·1
16·9
4·2 × 0·03 = 0·126 ft. 0·00126
1·00228
1·001514

23·3
19·0
4·3 × 0·03 = 0·129 ft. × 10 = 1·29
10·0129

21·14 × 0·388 = 8·3094 ft.
21·14 × 0·404 = 1·00644

(153)

Measurement of the Conductivity of the Iris Copper wire employed in Experiments made for determining the temperature coefficient of copper.

1st series 23rd July 20. Differential Astatic Mirror Galv. adjusted. Res. of both coils 13500 ω = 6750 ω each. Test of wire that had been used in previous experiments

No. of Obs.	Length of wire	Res. added	to	Sum	Ratio	Standard	Temp.	Res. at temp.	Res. of wire	Res. per cm.	Temp. wire
1	25·3	8313	wire	15,063	1·812	Legal ω 15°C	23·4°C	1·00237	1·816 ω	0·07177	23·4°C.
2	17·0	3777	"	10,527	1·559	"	"	"	1·563	0·09192	
3	61·95	·585	"	7,335	1·087	S. ω 15°C	23·3°	5·00645	5·4241	0·08752	
4	69·48	1490	"	8,240	1·221	"	"	"	6·111	0·08732	23·8°C
5	60·03	3245	"	7,095	1·0512	"	"	"	5·263	0·08768	23·2°C

2nd series October 20. Res. of Galv: both coils 13450 = 6725 ω each

No. of Obs.	Length of wire	Res. added	to	Sum	Ratio	Standard	Temp.	Res. at temp.	Res. of wire	Res. per cm.	Temp. wire
1	17·775	5700	wire	12,425	1·847	1·00250 N.S.	21·1	1·001514	1·8506	0·10407	22·7C
2	89·96	2150	10 ω	8875	1·320	1·00019	23·3	1·00129	0·7586	0·08430	21·4°
3	87·79	2360	"	9,085	1·351	"	"	"	0·7410	0·08440	21·4°
4											

The weight of the 17·775 cms was 0·0291 gms or 0·001637 gms per cm.
" " " 99·75 " " 0·1915 " " 0·001920 " " "
Allowing a sp. g. of 8·90 would give an area of 0·0002157 sq. cms or a diameter of 0·05214 cms or 0·002063"

0·08435 × 0·0002157 = 1820 ohs units @ 21·14°C.
= 1680 " " legal @ 15°C.
1·65 for 15°C
= 0·9666 conductivity of 16214

Galvanometer Constants

28th Oct: 20.

No. of Obs.	Deflection both sides	Substance	Weight before	Weight after	Gain	Accepted transfer	Transfer per sec.	Current	Check Deflection	Time per cm.	Time of Osc. after defl.	Damp per half-swing
1	300	Ag	12·1655 11·8732	11·7753 12·2564	−0·3902 +0·3832	0·3967	0·001289	1·1529	0·222	0·193	4·45814	0790
2	600	Cu	10·1343 9·3000	9·9067 9·5324	−0·2276 +0·2324	0·2290	0·0003216	1·1693	0·2287	0·1965	1·129149	9·7778

Measurement of the Inductances of various coils with the Leathmeter

No.	Coil	Bridge Ratio	Res: ohms	Batty.	Inductance henries	Inductance kilometres	Leads	Time res:	Temp.	Res: @ 0°C	Time Const @ 0°C seconds	T.O.
1	H.B gilling 11lb	1000/100	223.47	0.920	0.2056	2056	1.02	222.45	20.3°C.	206.25	0.000997	20.3 °C
2	10lb	"	223.77	"	0.2057	2057	"	222.75	"	206.5	0.000997	
3	121 lb	"	4416.57	1.820	0.8170	8170	-	4408.55	"	4113.1	0.000978	
4	W-b	"	4416.47	0	0	0	-	4405.85	"	4113.35		
5	p/w + b-wire	"	224.27	0	0	0	—	223.25	"	207.0		
6	bunch	1000/1000	224.20	2.790	0.2100	2100	-	223.28	"	208.0		
7	H.B gilling 100 lb	1000/1000	1248.1	0.1340	0.1747	1747	1.02	1247.1	"	1157.3	0.000157	19.5
8	" " b	"	2308.1	0.220	0.5475	5475	"	2427.1	"	2308.0	0.000237	"
9	Inductionless coil 12Ω	1000/5	13.135	1.5358	0.02016	201.6	1.00	12.135	19°C.	12.30	0.001782	"
10	Sec. of	"	"	1.1425	omitted	114.25	"	-	"	-		
11	" " "	"	-	1.6140	omitted	13.67	-	-	"	-		
12	pri	"	1.305	0.195	0.00255	25.45	-	0.305	"	0.282	0.009	

Experiment made to ascertain whether the gravitation force varied with the temperature of the attracting bodies.

Some preliminary experiments were tried on the 26th Oct. using an ordinary 18 c.p. electric lamp ~~of~~ weighed on the chemical balance and supplied with current by a pair of small copper wires dipping into mercury. No difference could be appreciated in the weight when the lamp was raised to vivid incandescence, the limit of distinct observation being 0.003 gms. The experiment was however of little value because the weight of the carbon filament was found to be only about 0.023 gms, so that a very great change in the weight would have passed unnoticed.

The experiment was repeated however with greater accuracy on the 27th with a special lamp as follows:— A special carbon lamp was made. The globe was a 50 c globe, and the filament a special carbon filament for 50 c.p. in a spiral the weight of the filament being 0.0405 gms. The diameter of the helix was 0.75 and there were 9.5 turns + 5.5 cms or 22.4 + 5.5 = 27.9 cms of filament. The cross-section was rectangular 0.0110" × 0.0075" = 0.0279 c × 0.0476 cm = 0.000133 sq

The weight of lamp and glass beaker over it (to reduce convection) was 1244.0 gms. The period of the balance for this load was 40 secs. for one double vibration. The wires first employed to make contact with the mercury in the tubes was 0.005" copper (0.0126) diam. The weight of these per cm = 1.127 mgm. or of two ~~0.0225~~ 0.00225 gms per cm. The length of the arms = 22 cms, and the length of the pointer 30.5. By using a magnifying glass, a displacement of about 0.1 mm could be detected. The mercury cups were formed of glass tubes 0.35 int and 0.45 ext. diam., bashed side by side, and upright. These reduced the period of vibration to 3 seconds.

A series of readings was made with this lamp, using a current of 1.97 amperes and 120 volts. In every case it was found that the weight diminished about 10 mgms permanently or subpermanently, after an application of the current, the lamp being brought to bright incandescence, and no change was noted at any time that could be attributed to variation in weight. The limit of appreciation was 0.002 gms, and a variation of 0.002 would certainly have been detected = 7.5%. The dipping wires were subsequently reduced to a diameter of 0.0025" 0.0065 cm, and this was the practical limit, since 0.002" or 0.005 cm, failed to carry the current. The following is a sample of the observations:—

21.11.20 Weight balancing 1244.0150

12.00 Current on. pointer at zero

.15 - off. pointer 0.002 say or half the breadth of zero line displaced in direction indicating less weight.

13.00	- - - - -	0.004 cms or whole breadth
13.30	- - - - -	0.004
14.00	- - - - -	0.003
14.30	- - - - -	0.002
15.00	- - - - -	0.002

Balanced afresh by 1244.000.

Traction Calculations.

Required the power and force to carry
20 trucks each 30 tons in weight (loaded) up a 1.5% gr. 5 mph.
" " " - - - - - 0.5% gr. 15 m.p.h.
" " " - - - - - level 15 . . .
the weight of the engine being estimated at 100 tons.

Total weight 1000 tons or 2000,000 lbs. 1.5% . 30,000 lbs.
haulage 7 lbs per ton = 7000
Total pull on 1.5% grade 37,000 lbs. at driving axle.
~~This is maximum pull.~~

Power at 5 mph. = 7.33 ft. per sec. = 271,300 ft lbs. per sec.
= 493 HP.
= 368 kwts.

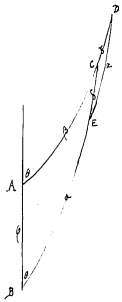
Total weight 1000 tons 0.5 % = 10,000 lbs.
haulage 7000
Total pull on 0.5 % grade 17,000 lbs. at driving axle

Power at 15 m.p.h. = 22 ft. per sec. = 374,000 ft lbs. per sec
= 680 HP.
= 507 kwts.

This is the maximum power to be exerted.
The power to be developed allowing 70% commn efficiency
= 725 kwts

With 100 volts at motor terminals = 7250 ampere
- 500 . - - - = 1450 - .

Power at 15 m.p.h. on level = 154,000 ft lbs. per sec.
= 280 HP
= 209 kwts developed
@ 70 % efficiency) this is = 300 kwts absorbed
at 100 volts @ mt. = 3000 ampere
- 500 - - = 600 .



θ

Calculation of the angle made by the tangents at any two points of a uniform helix, distant $(\varphi + 2n\pi)$ from each other, the angle of the helix being θ.

28th Oct: 20.

Let A and B be the two given points. Then projecting the great-circular arcs BEC, and ACD along the tangent lines of the helix the angle made by the two tangents will be the angle ED or x formed by the polar arcs E and D of these circular arcs respectively.

Then $\tan\left(\frac{\alpha+\beta}{2}\right) = \tan\frac{\varphi}{2}\,\frac{\cos\frac{1}{2}(2\theta-\pi)}{\cos\frac{1}{2}(\pi)} = \infty$

$\therefore\ \alpha+\beta = \pi$ or $\beta = \pi - \alpha$

but $\xi = \frac{\pi}{2} - \beta$

and $\delta = \alpha - \frac{\pi}{2}$

$\therefore\ \delta - \xi = -\pi + \alpha + \beta = 0$ or $\delta = \xi$.

while $\cos x = \cos\delta\cos\xi + \sin\delta\sin\xi\cos(\pi - C)$

$= \cos^2\delta + \sin^2\delta\cos(\pi - C)$

$= \cos^2\left(\alpha - \frac{\pi}{2}\right) + \sin^2\left(\alpha - \frac{\pi}{2}\right)\cos(\pi - C)$

$\therefore\ = \sin^2\alpha - \cos^2\alpha\cos C$ (1)

Also $\tan\left(\frac{\alpha-\beta}{2}\right) = \tan\frac{\varphi}{2}\,\frac{\sin(\theta - \frac{\pi}{2})}{\sin\frac{\pi}{2}}$

$\therefore \tan\left(\frac{\alpha-\beta}{2}\right) = -\tan\frac{\varphi}{2}\cos\theta$

or $\cot\alpha = \tan\frac{\varphi}{2}\cos\theta$

$\therefore\ \sin^2\alpha = \dfrac{1}{1 + \tan^2\frac{\varphi}{2}\cos^2\theta}$

and $\cos^2\alpha = \dfrac{\tan^2\frac{\varphi}{2}\cos^2\theta}{1 + \tan^2\frac{\varphi}{2}\cos^2\theta}$

Hence by (1) $\cos x = \dfrac{1 - \tan^2\frac{\varphi}{2}\cos^2\theta\cos C}{1 + \tan^2\frac{\varphi}{2}\cos^2\theta}$ (2)

$\sin C = \sin(\pi - \theta)\sin\varphi / \sin\alpha$

$\therefore\ \cos C = \sqrt{1 - (\sin^2\varphi\,\sin^2\theta)(1 + \tan^2\frac{\varphi}{2}\cos^2\theta)}$

$\therefore\ \cos x = \dfrac{1 - \tan^2\frac{\varphi}{2}\cos^2\theta\sqrt{1 - (\sin^2\varphi\,\sin^2\theta)(1 + \tan^2\frac{\varphi}{2}\cos^2\theta)}}{1 + \tan^2\frac{\varphi}{2}\cos^2\theta}$ (3)

If $\theta = 0$

$\cos x = \dfrac{1 - \tan^2\frac{\varphi}{2}}{1 + \tan^2\frac{\varphi}{2}}$ or $x = \varphi$

If $\theta = \frac{\pi}{2}$

$\cos x = 1$ or $x = 0$

If $\varphi = 0$ $x = 0$

$\varphi = \frac{\pi}{2}$ $x = 2\theta$

Gravitation Measurements contd.— 29th Oct.

Since the limit of certain detection in the experiments recorded on page 155 was only 7.5% up to visible incandescence say 1000°C, a special lamp was constructed of platinum wire, as follows:— A platinum wire 0.0125" (0.031) in diam and 20.2" 51.3 long) weighing 0.863 gm. was coiled into a helix of 18 spires and about 0.5 diam. This was sealed in a 50 c.p. globe and the latter exhausted. Four platinum wires of equal sizes 0.0125" formed the electrodes. This lamp was supported vertically under a beaker on the scale pan, and contact made into the mercury in the previously used tube by means of wire 0.0025" 0.00645 cm. diam. and 0.5 long, soldered on to the main copper electrodes of the lamp. It was found impossible to bring this lamp up to any high degree of incandescence, as ~~it lost~~ the platinum spiral lost rigidity, and threatened to collapse. A cherry red heat however was secured without difficulty, which may be estimated at 800°C.

The weight of lamp and beaker was 131.33 gm, and when working well, it was easy to read to one milligram. The first currents used lasted 20 to 30 secs, and were 1.5 amp, requiring 15 secs. to bring filament to luminous temp. Latterly, the current was raised to 2.9 amp, at which the collapse of the spiral became imminent after prolonged application. Red heat was then reached in 5 secs. In all the trials there was a distinct movement of the pointer in the direction indicating less weight for balance, within 5 secs. of the time of applying the current, and in most cases long before red heat was attained. This continued ~~for~~ steadily during the continuation of the current, but was permanent or sub-permanent, and appeared to have no connection with the temperature of the filament.

The movement noticed was supposed to be due in the first instance to the electromagnetic repulsion between the mercury and wire, followed by convection effect. It would have been possible to detect a change of 1 mgm in the weight of the filament while 3 mgms could not have escaped notice or 0.35%. The phenomena alluded to occurred with both directions of current, alike. The applications varied from 5 to 30 seconds. This test although the temperature attained was not so high as in the preceding cases, was considered conclusive, to the limit of accuracy stated, 4%.

Feeder Determination for Cincinnati O.

C.S. at 8th St Station

Feeder No.	Running via	Length feet	Average Empties	to	Drop needed	#	Drop obtainable	Cost per ft	Cost of feeder	Cost of total feeder	Cost per amp.
I	Elm + Pearl	5550	464	377	28	1000	28.0	3.96	21,980		
	Broadway	375	87	369	2	200	1.7	1.21?	454		
	Pearl	600	158	378	2	500	2.06	2.24	1,344		
	Pearl + Congress	1380	121	379	2	1000	1.8	3.96	5,465		
	Broadway	250	98	387	2	150	1.8	1.10?	275	29,518	$63.44
II	Elm + 4th	3900	581	358	25	1000	24.8	3.96	15,440		
	Main	420	213	367	5	200	4.7	1.21?	508		
	Fourth + Sycamore	1200	252	376	5	650	5.1	2.592	3,111		
	Fourth + Broadway	1450	116	318	5	350	5.2	1.856	2,691	21,750	$7.00
III (1+2)	Garfield + Vine	3700	206	373	24.5	{1000 / 1000}	24.5	7.920	29,300		
	Pearl	480	786	374	5.5	750	5.5	2.80?	1,344		
	Pearl + Walnut	1200	420	389	5.5	1000	5.5	3.96	4,752	35,396	$34.36
IV	Garfield Race + 2nd	4250	610	383	20	1000	28.6	3.96	16,830	16,830	$37.40
V	Elm	2850	793	371	25	1000	24.9	3.96	11,290		
	Elm	300	120	381	5	100	3.3	1.00?	300		
	Pearl	450	673	372	5	650	5.0	2.592	1,167	12,757	$14.19
VI	Vine + 5th	3100	671	329	23	1000	22.9	3.96	12,280		
	Fountain Sq.	570	310	320	7	200	6.5	1.472	839		
	Walnut	450	361	357	7	250	7.0	1.344	605	13,724	$20.40
VII	Garfield + Race	2200	872	346	21.0	1000	21.0	3.96	8,712		
	Race	500	481	354	9	300	8.8	1.472	736		
	Race + Third	1350	391	365	9	650	9.0	2.592	3,500	12,948	$14.05
VIII	Garfield + Vine	2550	613	347	17	1000	17.2	3.96	10,100	10,100	$16.40
IX	Elm	1080	905	314	11	1000	10.8	3.96	4,280		
	George, Race + 4th	1200	281	308	6	600	6.1	2.48	2,976		
	Elm + 6th	750	65	304	6	100	5.3	1.00?	750		
	George + Race	700	301	315	6	400	5.5	2.00	1,400		
	Elm	650	258	345	6	300	6.0	1.472	957	10,363	$11.45
X	Ninth	1420	438	410	10.5	650	10.5	2.592	3,681		
	Ninth	960	99	274	6.5	150	6.9	1.10?	1,056		
	Vine + 6th	1500	175	317	6.5	450	6.3	2.096	3,144		
	Ninth + Main	2150	164	264	6.5	600	6.4	2.480	5,333	13,214	$20.18
XI (1+2)	Eighth + Central	1600	959	322	8.5	{1000 / 1000}	8.4	7.920	12,670		
	Central Ave	520	416	343	8.5	200	7.8	1.472	765		
	Central 5th + John	1400	543	349	8.5	1000	8.3	3.960	5,543	18,978	$19.73
XII	Central + 7th	3000	327	321	21.5	500	21.3	2.240	6,720		
	Butler + 9th	1275	147	302	8.5	250	8.2	1.344	1,713		
	Butler, 6th + Stone	1620	180	339	8.5	350	9.0	1.856	3,006	11,439	$24.48
XIII	Plum	780	316	530	9.0	300	9.0	1.472	1,148		$3.10.55
	Seventh	500	138	206	5.0	150	5.0	1.10?	550		
	Seventh	500	178	313	5.0	200	4.75	1.21?	605	2,303	$7.74
XIV	8th, Central Ave, + 9th	3700	287	301	24.75	400	27.75	2.00	7,400		
	9th + Freeman	1050	58	311	2.25	300	2.2	1.472	1,545		
	Baymiller	580	129	281	2.25	350	2.2	1.856	1,076	10,021	$24.02
		66010	8332						$219,341	219,341	

Elm + Plum St.

Feeder Estimate for Cincinnati C. S.

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Feeder No.	Running via	Length	Drop	to	Drop needed	#	Drop obtainable	Cost per ft	Cost of feeder	Cost of Total feeder	Cost per amp.
		66,010	8332								
XV	Plum 8th, Central + 8th	1425	287	531	10	450	9.9	2.096	2,987	219,341	219.341
	John + 9th	780	91	304	7	100	7.7	1.00?	780		
	John 9th + Mound	1400	80	287	7	200	6.2	1.21?	1,694		
	Eighth	600	216	532	4	350	4.0	1.856	1,114		
	Eighth + Butler	900	56	321	3	200	2.7	1.21?	1,089		
	Mound	760	160	331	3	300	2.8	1.472	1,119	8,783	$30.60
XVI	Central Park Lane + Fourth	5050	251	241	25	550	25.1	2.384	12,040		
	Baymiller + Wade	1800	89	205	5	350	5.0	1.856	3,341		
	Baymiller Laurel Freeman	920	69	243	5	150	4.6	1.10?	1,012	17,251	$62.72
XVII	9th, Central Ave.	2100	381	253	9	1000	8.8	3.96	8,315		
	Clark + Linn	2460	90	242	8	300	8.0	1.472	3,620		
	Clark	1250	173	247	8	300	7.8	1.472	1,840		
	John + Everett	1920	118	234	8	300	8.2	1.472	2,825	16,600	$42.57
XVIII	Ninth + Central	2400	143	252	15.5	250	14.9	1.344	3,226		
	Central	210	72	253	1.5	100	1.7	1.00?	210		
	Central	600	71	231	1.5	250	1.8	1.344	807	4,243	$29.46
XIX	Ninth + Elm	3420	341	213	23	550	23.1	2.384	8,152		
	Elm + Findlay	1750	136	508	7	350	7.4	1.856	3,247		
	Liberty	950	120	215	7	200	6.2	1.21?	1,150		
	Liberty + Central	1440	85	212	7	200	6.7	1.21?	1,743	14,292	$41.91
XX	Elm + 14th	3350	214	227	12.0	650	12.2	2.592	8,684		
	Elm	1050	105	213	4.8	250	4.8	1.344	1,411		
	15th, May, Liberty	1725	109	217	4.8	400	4.9	2.00	3,450	13,545	$63.79
XXI	Elm, Court, Race	2040	349	266	13	600	12.9	2.480	5,060		
	12th Vine	1170	140	265	4	450	4.0	2.096	2,452		
	Twelfth	430	201	267	4	250	3.7	1.344	578	8,090	$23.18
XXII	Elm, Court, Main, Woodward	4250	224	259	25	400	24.9	2.000	8,500		
	Woodward + Broadway	1200	87	219	5	250	4.9	1.344	1,728		
	Woodward + Hamilton	1320	52	415	5	150	5.0	1.00?	1,452		
	Sycamore + Abigail	760	85	263	5	150	4.7	1.00?	836	12,535	$55.96
XXIII	Ninth + Elm	780	266	275	9	250	8.9	1.344	1,048		
	Court	900	112	279	8	150	7.4	1.00?	990		0.5 cents at C.S.
	Court	990	78	272	8	120	7.1	1.00?	1,040		
	Court + Race	1260	76	294	8	150	7.2	1.00?	1,386	4,464	$16.78
XXIV	9th, Central, Lincoln + Baymiller	6450	348	533	25	1000	24.7	3.96	25,540		
	Poplar + Western	1100	75	202	5.3	150	5.9	1.21?	1,331		
	Baymiller	1080	54	525	5.3	120	5.3	1.00?	1,188		
	Baymiller	1650	219	516	4	1000	4	3.96	6,534		
	Dayton	1080	74	519	1.3	600	1.5	2.48	2,678		
	Baymiller	900	70	515	1.3	500	1.4	2.24	2,016		
	Dayton	650	75	517	1.3	400	1.3	2.00	1,300	40,587	$116.66
		133,160	8228						$359,731	$359,731	

6500 lts
4500 #
3370 Kurts.

$5.535 per amp.
$33.34 per amp.

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